Samara

The International Newsletter of the Millennium Seed Bank Partnership

Special issue featuring projects and research from The Global Tree Seed Bank Programme, funded by the Garfield Weston Foundation

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Juglans pyriformis in the State of Veracruz

Photo: Pronatura Veracruz

Conserving and investigating native tree seeds to support community-based reforestation initiatives in Mexico

Mexico is the fourth richest country in the world in terms of plant species diversity, after Brazil, China, and Colombia with a flora of ca. 23,000 vascular plants. Around half of the plant species are endemic and nearly 3,500 are trees.

ELENA CASTILLO-LORENZO (Latin America Projects Coordinator, RBG Kew), MICHAEL WAY (Conservation Partnership Coordinator (Americas, RBG Kew) & TIZIANA ULIAN (Senior Research Leader – Diversity and Livelihoods, RBG Kew)

Trees and forests provide multiple goods and benefits for humans, such as high-quality wood, fruit, honey, and other ecosystem services, including clean water, prevention of soil erosion and mitigation of the impacts of climate change. However, despite their recognised importance, trees in Mexico are subject to a wide range of threats, such as habitat destruction leading to deforestation, the use of exotic species for reforestation which compete with native species, and climate change. (Vázquez-Yanes & Batis, 1996).

The project 'Science-based conservation of tree species in Mexico' started in 2015, as part of the Global Tree Seed Bank Programme (GTSBP), in collaboration with the Facultad de Estudios Superiores Iztacala of the Universidad Autónoma de México (Fes-I UNAM). The aim of this project was to conserve tree species through a collaborative research programme focusing on endemic, protected and useful trees important for the livelihoods of rural communities.

Fes-I UNAM partners in collaboration with Kew managed to collect and store almost 400 tree species *ex situ* in country, 354 of which have been duplicated at Kew's Millennium Seed Bank. Seed research has been carried out on 314 species to study their tolerance to desiccation for seed banking and to determine germination requirements to inform propagation activities. One of the key project species is *Cedrela odorata* (Spanish cedar), whose conservation status is vulnerable (IUCN 2020) due to exploitation for its highly valued wood. *C. odorata* is also used for medicinal purposes by local communities in Mexico, with the leaves being prepared in herbal tea to treat toothache, earache, and intestinal infections. We investigated the germination requirements of *C. odorata* seeds (between zero and 50°C, Sampayo-Maldonado et al., 2019) and modelled these under future climate scenarios.

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Millennium Seed Bank Partnership 20th Anniversary

Royal Botanic Gardens Kew

We concluded that this species will be able to germinate faster under predicted future warmer temperatures in Mexico.

Through the creation of distribution maps, we have identified the state of Veracruz as a conservation hotspot for tree diversity in Mexico (Téllez et al., 2020) and we have established a new partnership with the NGO Pronatura Veracruz (PV). This institution has experience in plant propagation and works with a wide network of tree nurseries to support reforestation activities in the region. As part of the next phase of the project we are now working with Fes-I UNAM and PV to conserve native trees, through seed banking and in seed orchards, and to support community-based reforestation initiatives in the state of Veracruz.

Photo: E. Castillo-Lorenzo

Seedlings at the Pronatura Veracruz 'cloud forest' nursery, near Coatepec, Mexico.

Photos: S.Sampayo-Maldonado / C.Ordoñez

Seedlings of *Cedrela odorata* in the FES-I UNAM glasshouse.

The Mexican team and Kew staff at Fes-I UNAM in Mexico City during a project visit in May 2019.

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Working with communities to safeguard Madagascar's trees

SOLOFO ERIC RAKOTOARISOA (Ecosystems Team Leader, Kew Madagascar Conservation Centre)

According to recent research, about 59% of tree species in Madagascar are threatened with extinction (Beech et al., 2020). Since the start of the tree conservation programme, 3,500 seed collections representing over 900 species have been made. These collections include 119 families, with the top five families being Fabaceae, Rubiaceae, Malvaceae, Euphorbiaceae and Moraceae.

In Madagascar, the project adopted a novel approach to seed banking by involving local communities. About 290 households from 117 villages have been engaged in seed collecting activities. These communities have been trained in data gathering and seed and plant specimen collection techniques. Involving communities in the project has many benefits, as they become aware of the value of their forest and are encouraged to become partners for conservation in Madagascar. In addition, many species that have not previously been collected by the Millennium Seed Bank have been found by communities (such as the new species of *Peponidium*, pictured).

However, the importance of following the specimen collecting techniques must be emphasised. Poor quality herbarium specimens cause difficulties in plant identification. Also, many collections were found to be recalcitrant, as communities were not able to easily distinguish between orthodox and recalcitrant seeds.

Despite a few problems, many rare and threatened species were collected during the project. Some species collected are critically endangered, such as *Dypsis leptocheilos*. Collections were made of five of the six endemic species of baobab in Madagascar, as well as species from four of the five endemic families: Asteropeiaceae, Sarcolaenaceae, Physenaceae and Sphaerosepalaceae. Many of those species, which remain unidentified at present, could be new to science.

Photo: Solofo Rakotoarisoa

New species of Rubiaceae (*Peponidium* sp. nov.).

Photo: Ando Andriamanohera

Fruit of *Adansonia suarezensis*, collected in December 2019.

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A message from Colin Clubbe

(Head of Conservation Science, RBG Kew)

The COVID-19 pandemic has changed the world and will likely change the way we live our lives in the future. The pandemic has exposed the fragility of our global society, impacting our food, water and medical supplies, our very livelihood.

Writing from my spare bedroom, which has been my office for ten weeks of lockdown, the one grain of hope I have is seeing a recognition of the importance of nature-based solutions, and the value people are putting on contact with nature. This contrasts starkly with the shocking reports we have seen this year on the negative impacts we are having on biodiversity.

The IPBES Global Assessment Report estimates that more than one million species may be at risk of extinction. The World Economic Forum Global Risks Report lists biodiversity loss as a top five global risk, stating that biodiversity loss puts our food supplies and medical care at risk, and must be stopped. Just yesterday, the World Resources Institute published its review of the 2019 global tree cover data, showing we lost a football pitch of primary rainforest every six seconds in 2019. What still inspires me and gives me hope for the future is the role that the Millennium Seed Bank Partnership continues to play in global conservation.

This issue of Samara highlights this hope, with an extraordinary range of inspiring stories about global conservation action saving trees, achieved by generous funding from the Garfield Weston Foundation. Thanks for your commitment to global conservation and to the importance of sustaining a healthy environment.

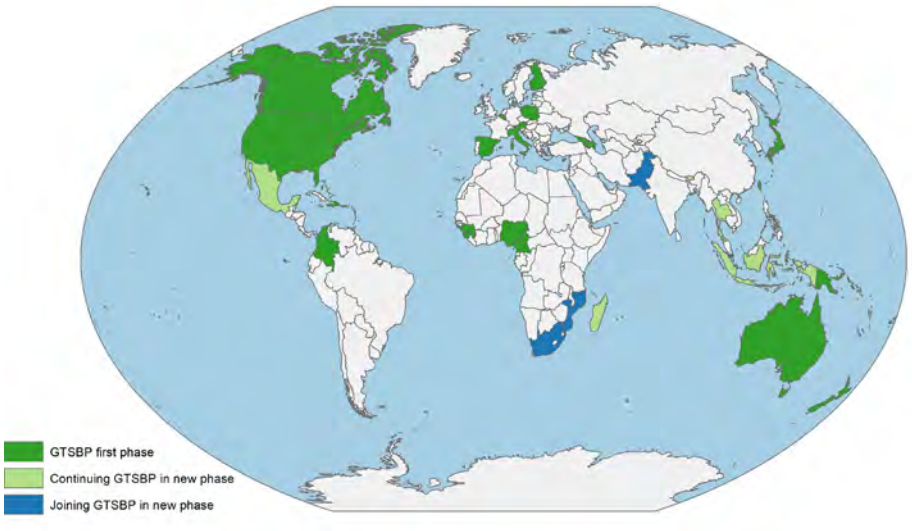
A message from Elinor Breman on the success of the GTSB Programme

(Senior Research Leader, Seed Conservation, RBG Kew)

Despite the current global focus on reforestation and the biodiversity and carbon offset benefits offered by trees, understanding and conserving the world's most threatened trees has never been more important. Traditionally, trees are underrepresented in wild seed banks – partly due to the difficulties in collecting them, some of which have been outlined in this issue (p. 4, 5 & 6). With funding from the Garfield Weston Foundation, the Global Tree Seed Bank was established at Kew's Millennium Seed Bank in 2015.

Since then, project partners have gone on to collect 3,863 tree and shrub species from across the world, beating the original target of 3,000 by some margin. This fantastic achievement was made possible by a network of 54 partners from 35 countries and regions (North America (3), South America (1), the Caribbean (7), Europe (7), Africa (5), Asia (8) Australia (1) and Pacific Islands (3)) several of which were new to the MSB Partnership. As with all MSB programmes, training and technology transfer were at the heart of this success story. More than 340 people were trained in seed conservation techniques from 2015–2019, either in country or at the MSB. In addition, 15 blue drum kits (mini seed banks) were sent to partners in Africa, Asia, the Caribbean and the Pacific, while four new seed banks were also created: in the National Botanical Garden of Santo Domingo, Dominican Republic; at the IRAD-National Herbarium in Cameroon; at UGAN-C-National Herbarium of Guinea; and in the Institute of Botany in Azerbaijan. The programme advanced our knowledge of tree species around the world through research projects in Colombia, the Dominican Republic, Georgia, Italy, Japan, Mexico and New Zealand – a number of these projects are described in this issue (p. 1, 6 & 7). Closer to home, four research fellowship projects were undertaken at Kew (p. 8 & 9). Also featured are a selection of other tree related activities at Kew, supported by other donors and funders (p. 14 & 15). My thanks to everyone who has contributed to this special issue of Samara, and to the Global Tree Seed Bank programme.

Countries and Regions Contributing to the Global Tree Seed Bank Programme



Seed banking for forest restoration in Thailand

GREUK PAKKAD (Research Officer, Forest Restoration Research Unit, Chiang Mai University) & STEPHEN ELLIOTT (Co-director, Forest Restoration Research Unit, Chiang Mai University)

Photo: Greuk Pakkad

FORRU-CMU staff and interns collecting tree seeds for the Global Tree Seed Bank Programme Thailand.

Lack of seed supply networks of indigenous forest tree species seriously limits forest restoration initiatives, at a time when enthusiasm for ecological restoration has never been higher. In northern Thailand, Chiang Mai University's Forest Restoration Research Unit (FORRU-CMU) has developed a framework species approach to the restoration of tropical forest ecosystems. This involves planting at least 20 to 30 tree species, characteristic of the target forest ecosystem, that catalyse and accelerate natural forest regeneration.

But propagating so many species is challenging, since framework species produce seeds at different times of the year, with varying lengths of dormancy, and their seedlings grow at different rates. Improved seed storage and banking for developing seed supply networks would enable wider use of this highly efficient forest restoration technique.

Consequently, FORRU-CMU welcomed the opportunity to work with RBG Kew, in partnership with Thailand's Department of National Parks' Forest Herbarium (BKF), sponsored by the Garfield Weston Foundation. FORRU-CMU staff benefited from training by Kew staff in seed collection planning, seed processing and storage, which has greatly improved seedling production and direct seeding protocols in our restoration trials. From March 2016 to February 2019, the two Thailand partners banked seeds of 244 priority tree species at Kew's Millennium Seed Bank.

Both framework tree species and several rare species were collected, so that, should any of them be wiped out by forest fires or other disasters, tree species vital for ecological restoration could be revived from the banked collections. The project complemented and supported national efforts to manage forest genetic resources, including work to establish a national seed bank in Bangkok, which is now operational.

Bushfires just one of many challenges confronting Australia's seed collectors

JESSICA NICHOLS (Australian Seed Bank Partnership graduate) & DAMIAN WRIGLEY (National Coordinator, Australian Seed Bank Partnership)

Last year marked the Australian Seed Bank Partnership's (ASBP) fifth and final year of collecting as a Millennium Seed Bank Partnership (MSBP) Asia-Pacific partner in the Garfield Weston Foundation Global Tree Seed Bank Programme (GTSBP), with bushfires being just one of many challenges facing the seed collectors during this time.

Our intrepid and resourceful partners collected over 500 taxa across 32 bioregions, making a substantial contribution to the conservation of 3,000 of the rarest, most threatened and most useful trees globally. The ASBP focused on collecting Australia's endangered, endemic and economically significant tree species, including the following notable collections.

Photo: Luke Sweedman, BGPA

The resourceful Botanic Gardens and Parks Authority team collected from boabs (*Adansonia gregorii*) in the Kimberley region as part of the Global Tree Seed Bank Programme.

The Brisbane Botanic Gardens team collected seed from six *Ficus* species in Far North Queensland's wet tropics, including endemic and ecologically significant banana fig species *Ficus crassipes*, an important food source for the nationally endangered spectacled flying fox (*Pteropus conspicillatus*). After collecting in subtropical regions of New South Wales, the Royal Botanic Gardens and Domain Trust team encountered problems with storing *Caldcluvia paniculosa* seeds, delaying their shipment to the MSB. Such challenges have enhanced the ASBP's knowledge of rainforest tree seed storage behaviour.

Western Australia's Botanic Gardens and Parks Authority team endured vast distances and sweltering heat to visit the remote Pilbara and Kimberley regions, collecting seeds of the boab tree (*Adansonia gregorii*) – a tree valued by Australia's indigenous people for its edible fruits, medicinal uses and water-holding properties. In Tasmania, extensive bushfires on the west coast coincided with *Acradenia frankliniae* dispersing its seeds, forcing the Royal Tasmanian Botanic Gardens team to abandon a collecting trip. Bushfires are just one challenge facing seed collectors in Australia, along with drought, floods, seasonal variation and the impact of pathogens like myrtle rust (*Austropuccinia psidii*). Seed predation in *Lomatia fraseri* (tree lomatia) was one challenge the Royal Victorian Botanic Gardens team overcame by trekking to higher altitudes where the cooler air and shorter growing seasons appeared to limit the incidence of predation.

Photos: RBGDT

Caldcluvia paniculosa was originally collected as part of the Global Tree Seed Bank Programme.

The Australian National Botanic Gardens and the George Brown Darwin Botanic Gardens teamed up to collect across Victoria River Downs and Gregory and Kakadu National Parks, exchanging seed-collecting knowledge and techniques with traditional landowners to secure 29 collections for the GTSBP.

The Botanic Gardens and State Herbarium of South Australia team undertook a 3,000 km round trip to the remote Anangu Pitjantjatjara Yankunytjatjara Lands, a Native Title area in the far north west of South Australia, securing a collection of the nationally vulnerable Mount Illbillie mintbush (*Prostanthera nudula*).

The ASBP's engagement with indigenous groups during the GTSBP has contributed to building mutually beneficial conservation and restoration-focused collaborations between Australia's scientific bodies and its First Nations people.

The GTSBP provided a valuable opportunity for the ASBP, as part of the MSBP, to support the achievement of Target 8 of the Global Strategy for Plant Conservation. Through this project, the ASBP have also achieved our goal under Phase One of our 1000 Species Project, securing more than 1,100 endangered or economically significant species since 2012. Duplicates of these collections are housed at the Royal Botanic Gardens, Kew, aiding the important work of the MSBP in protecting global plant diversity.

Photos: Fanny Karouta-Manasse, ANBG

The ASBP collecting team collecting with Traditional Owners in Gregory National Park.

Challenges of tree seed collecting in Austria

CHRISTIAN BERG (Head of Botanical Garden, Graz), ADRIANA ATANASSOVA, MARTINA PÖLTL & PATRICK SCHWAGER (PhD students, Graz University)

Photos: P. Schwager

Collecting fruits of *Sorbus austriaca* on a rock face near Gesäuse National Park, Styria, Austria.

The Botanical Garden of Graz University (Austria) was engaged in the Global Tree Seed Bank Programme from 2015 to 2017, with a target list of 51 Austrian woody plant species.

Tree seed collecting, even from frequent, well-known species, is a challenge and requires longer preparation than other seed collecting projects – timeframes of five to seven years for future projects would be preferable. Extreme weather, insect infestations and planted individuals are other problems to consider. For some species with populations changed by genetic pollution, this project came at just the right time.

Population structure and fruiting trees

Under natural conditions, trees do not blossom every year, so fruiting trees can be rare or distributed irregularly. The period of seed maturity differs from north to south and across altitudes. Many seeds, for example of *Carpinus betulus, Crataegus monogyna, Fagus sylvatica* and *Ostrya carpinifolia,* mature slowly and need to be collected over a longer timeframe. This leads to large distances between individual fruiting trees, and a collection period of several weeks. It is also challenging to identify what constitutes the extent of a population.

Environmental extremes

A late frost or dry summer weakens fruiting species and makes them more vulnerable to pests. Due to the late frost in April 2016, the flowers (and therefore the fruits) of *Prunus spinosa* were almost completely eliminated. Woody species need one or two years to regenerate, so the three-year collecting period seems too short for woody plants.

Pathogenic infections

The harvest of *Prunus spinosa* was also impaired by an infestation of caterpillars (probably *Yponomeuta padella*). Hazel (*Corylus avellana*) suffered from a fungal infestation and probably nut weevil (*Curculio nucum*), although many fruits were still produced. Most nuts of wild populations were affected in some way; empty *Ulmus minor* fruits are uncommon in south-east Styria, but fruits were damaged by insects and leaves were badly affected by gall mites. Insect infestation was also observed in *Fagus sylvatica*, where nuts were damaged by *Diptera* larvae hatching a few days after storage.

Naturally occurring vs. planted individuals

Some species, like *Torminalis glaberrima*, *Tilia cordata*, *Pyrus pyraster* and *Acer platanoides*, are not rare, but individuals do not bloom in dense forests. When we find flowering and fruiting individuals in forest edges or hedgerows, the question arises: are they planted and therefore unlikely to be autochthonous? For highly used timber trees like *Fagus sylvatica* or *Picea abies*, this question is always present.

Genetic pollution

Due to the possibility of hybridisation, many species no longer exist in their pure genetic form. Unambiguous determination becomes difficult if the primary description of the species is used. This is especially true for crop wild relatives (e.g. *Prunus avium, Malus sylvestris, Pyrus pyraster, Cornus mas*) but also for *Ulmus* species and *Betula pubescens*. Many collections thus had to be discarded after evaluation.

The problem of the rarity of pure populations was confirmed by taxonomic specialists. For some species (*Malus sylvestris, Pyrus pyraster*) we gave up trying to find suitable seeds.

Photos: A. Atanassova

Tilia platyphyllos with fruits on a forest edge. Indigenous or planted?

Seed collectors versus deer on Japan's Kyushu Island

BUNTAROU KUSUMOTO (Postdoc Researcher, University of the Ryukyus), TSUTOMU ENOKI (Associate Professor, Kyushu University), AKINORI FUJI (PhD candidate, University of the Ryukyus) & YASUHIRO KUBOTA (Professor, University of the Ryukyus)

Photo: B. Kusumoto

Deciduous forest in Miyazaki, Kyushu. The vegetation cover on the forest floor is very limited because of heavy deer browsing.

Japan's Kyushu Island harbours a diverse mix of tree species along a wide range of climatic and topographic conditions and is where the team from the University of the Ryukyus and Kyushu University has been tree seed collecting.

Currently, the forest is facing a serious problem: an overabundance of native sika deer. The deer population has been growing dramatically over the last two decades, leading to severe damage to vegetation. For tall trees, bark-stripping can reduce survival and growth rates. The leaves, branches and reproductive organs of shrubs are damaged by browsing, with seedlings eaten immediately after germination.

Seed collectors need to adjust their sampling strategy to compete for resources with the deer. It may be necessary to select species that are less impacted because of the need to sample a good quantity of seeds without damaging the plant population dynamics. Such selection may bias seed collections to those that are toxic or unpalatable to deer. Moreover, some species that urgently require conservation may be missed.

Seed collectors face a difficult decision. If the functioning of natural processes is to be prioritised, it may be decided to avoid sampling some of the most vulnerable populations, although any seeds that are left to germinate are less likely to survive due to grazing pressure.

However, if the focus is on *ex situ* conservation, due to the practical difficulties of *in situ* measures, such as deer exclusion in mountainous areas, collectors may actively target those populations most impacted by deer. Currently, the team are taking the former approach, although the second approach is being considered.

Cryopreservation of *Syzygium maire* (swamp maire, maire tawake), a critically endangered tree species from New Zealand

KARIN VAN DER WALT (Conservation and Science Advisor, Otari Native Botanic Garden)

Syzygium maire is a tree that grows in waterlogged ground ranging from swamplands to riverbanks, where it often forms dense forests and can reach up to 16 m tall. This species is endemic to New Zealand and its critically endangered status can be attributed to a 70% population reduction, coupled with a significant threat from the fungal pathogen *Austropuccinia psidii* (myrtle rust), which was confirmed in New Zealand in 2017. During the summer months, *Syzygium maire* produces large red fruit (10–20 mm in size). These fleshy fruits are highly sought after by native birds including the New Zealand pigeon (kererū), which swallows fruit whole so acting as an important dispersal agent.

Photos: Karin van der Walt

Six-week-old explants grown *in vitro* from isolated embryos.

As with all studied *Syzygium* species globally, the seed of *S. maire* is highly sensitive to desiccation. Effective germplasm storage therefore requires cryopreservation of isolated embryos. At the Lions Otari Plant Conservation Laboratory, we have optimised seed collection time, embryo excision and decontamination, and are now assessing the effects of rapid desiccation, cryoprotection, rate of cooling/thawing, rehydration and recovery of embryos to inform cryopreservation.

Our findings illustrate that the embryos are shed at high water content (65% fresh weight basis) and are sensitive to desiccation with significant viability loss following desiccation to water contents below 30%, both characteristics of recalcitrant seeds. Although survival following rapid desiccation is low, we are now researching the use of antioxidants and cryoprotectants to increase embryo survival following desiccation and exposure to liquid nitrogen (cryopreservation).

Syzygium is the largest flowering woody genus in the world and with the centre of endemism in the Pacific Region, finding an effective way to secure the seed is crucial, especially with increased pressure from climate change and pathogens.

Mature berries of *Syzygium maire*.

New protocol for processing short-lived *Salix* seeds trialled at National Seed Bank of Georgia

TINATIN BARBISHVILI (Deputy Director, National Botanical Garden of Georgia)

In June 2019, at the National Seed Bank of the National Botanical Garden of Georgia (NBGG), training in a new protocol for processing short-lived *Salix* seeds was provided by a team from the Millennium Seed Bank (MSB).

Seeds of *Salix* (willow), although orthodox, are known to be short-lived. If processed appropriately, however, they can remain viable for years stored at low temperature and moisture conditions (López-Fernández et al., 2018). In early 2019 the MSB's seed collections team reported that seeds of eight species of *Salix (Salix alba, S. armeno-rossica, S. caprea, S. excelsa, S. kikodseae, S. pseudomedemii, S. triandra, S. wilhelmsiana)*, collected in 2018 by NBGG and the Institute of Botany of Ilia State University as part of the Global Tree Seed Bank Programme, had undergone a complete loss of viability.

To address this, Dr Aisyah Faruk, MSB Country Programme Officer for the Caucasus, suggested a training course in a special protocol for post-harvest processing of *Salix* seeds. The training took place at the NBGG seed bank in Tbilisi, with June being chosen to coincide with the optimum maturity of seeds of several *Salix* species. MSB Seed Collections Manager, Janet Terry, introduced the new protocol for collecting, processing and storing *Salix* seeds, using a sample of *Salix elbrusensis* seeds from Armazi valley, near Mtskheta.

Janet and five staff members from NBGG travelled to Kazbegi Municipality in the Great Caucasus Mountains. On the road to Stepantsminda, seeds of *Salix alba* were collected, although they turned out to be immature and not suitable for collection. The next destination was the Khde river valley, near the border with Russia.

Photo: Elene Japaridze

Mamuka Dolenjashvili, Ana Kvlividze and Janet Terry in the Khde Valley en route to collect *Salix kuznetzowii* and *Salix pentandroides* seed.

The team hiked up a steep rocky slope to collect seeds of *Salix kuznetzowii* and *Salix pentandroides*. Returning to the seed bank and using the new protocol, the seeds were unpacked inside the dry room, taking note of the number of thick green seeds and brown wrinkled ones. In general, the seeds were considered mature if one-third of the catkins had started to 'fluff up'. Checking seed quality revealed that only those seeds of *Salix pentandroides* and *Salix elbrusensis* were sufficiently mature.

The seeds were then dried in open containers or paper bags in the dry room, allowing the seed dispersal unit, the pappus, to 'fluff up' to achieve the appropriate level of maturity. After drying, the seeds were cleaned using sieves, with the pappus being separated using a vacuum cleaner. Empty seeds were removed using an aspirator, and a cut test was used to determine the proportion of full and empty seeds. The seeds were then put back into the dry room for a maximum of one week. After sealing in aluminium bags, the seeds were transferred to -20°C for long-term storage. Pre-storage germination tests revealed the collections to be of high quality.

In February 2020, testing at the MSB confirmed that all 2019 collections of *Salix (Salix apoda, S. caucasica, S. elbursensis, S. kuznetzowii, S. pentandroides)* as well as of *Populus hyrcana*, processed using the new protocol, produced a high germination percentage, indicating a good level of viability. Test results of duplicate collections retained at NBGG after six months of cold storage revealed that all the collections germinated within a week of sowing with a germination percentage of 75% to 100%.

Photo: Elene Japaridze

Janet Terry, Tinatin Barblishvili, Tsira Mikatadz-Pantsulaia and Ana Gogoladze checking the status of *Salix alba* seeds on the way to Stepantsminda.

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Cryobiotechnology for recalcitrant European tree seeds

DANIEL BALLESTEROS (Research Fellow, Comparative Plant and Fungal Biology, RBG Kew) & HUGH W. PRITCHARD (Senior Research Leader, Comparative Seed Biology, RBG Kew)

About 33% of all tree species (near 50% if focusing on tropical trees) may produce desiccation-sensitive (recalcitrant) seeds that cannot be preserved in conventional seed banks. Consequently, the long-term *ex situ* preservation of these species can only be accomplished by cryobiotechnologies (Pence et al., in press).

From 2015 to 2019, we investigated the cryobiotechnology of embryonic axes of temperate trees, mainly from the genera *Quercus* sp. (oak) and *Aesculus* sp. (horse chestnut). The aims were to: determine the extent and variability of desiccation sensitivity at the seed and embryo level; identify the optimum explant for cryopreservation, taking into account drying rates and the physical size of the explant; and optimise the route to maximum recovery of explants *in vitro*.

By combining the findings from these approaches, it was possible to develop a generic strategy for the cryopreservation of tissues of oaks and horse chestnuts based on work on >10 species (Ballesteros et al., 2019; Butel et al., 2019). Successes have been achieved with the cryobanking of pollen and the embryonic axes of many of the species (Ballesteros et al., 2019; Butel et al., 2019); for example, *Q. pyrenaica* (Figure 1). However, significant inter-species differences in stress tolerance were noted. These are possible due to variations in explant morphology, which we are exploring through the use of micro-computer tomography (microCT), for example. This technique is revealing subtle differences in ultrastructural traits of embryonic axes that relate to cryopreservation success (Figure 2).

Taking a multidisciplinary approach is underpinning advances in cryobiotechnology within the Kew Cryosphere (Willis et al., 2018). As the conservation status of many species with recalcitrant seeds is of concern, we remain advocates for the immediate implementation of cryobiotechnologies to help preserve biodiversity (Ballesteros et al., 2019; Pence et al., in press).

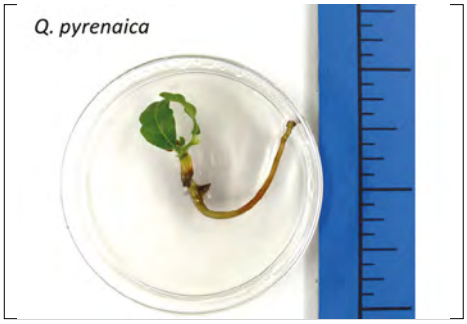

Figure 1: Germination *in vitro* of *Quercus* sp. embryonic axis after cryopreservation by fast drying and cooling.

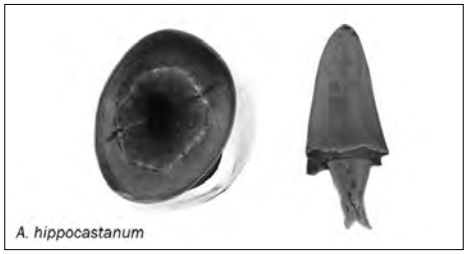

Figure 2: 3D reconstructions of *Aesculus* sp. embryonic axis after x-rays micro-computed tomography.

Photos: Daniel Ballesteros / Maria Conejero

ACKNOWLEDGEMENTS / REFERENCES:

Co-funding was provided by the EU Erasmus+ programme, the Stanley Smith (UK) Horticultural Trust, Nong Nooch Tropical Botanical Garden and Mahidol University. Thanks to MAPAMA, Lebanese University and Kyoto University for supplying additional seed material.

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Applying novel DNA sequence techniques to conserve South-East Asia's forests

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Photo: William J. Baker

Lanjak Entimau Wildlife Sanctuary – one of Borneo's most extensive forest reserves.

Nowhere are the challenges posed by climate change more daunting than in tropical forests, and nowhere are these challenges more pressing than in South-East Asian (i.e. Indo-Pacific) forests.

To enhance our ability to tackle these challenges, and to improve our predictive capabilities to better inform the conservation of these forests, we need to generate robust fundamental DNA sequence data to shed light on how the different tree genera are related to each other. To enable this, we have developed a novel DNA bait kit that allows us to capture and sequence over 300 single-copy genes for all flowering plants. This kit is now being applied to generate sequence data for the tree genera of South-East Asia.

Already, DNA has been extracted and sequenced for several hundred of the c. 600 tropical tree genera growing on the island of New Guinea. We are now poised to analyse these data to provide the first ever insights into evolutionary relationships between the trees found in New Guinea and how these have assembled into extant tropical forests.

These data will enable us to model how past environmental events, such as climate change or geological processes, have impacted the diversity and distribution of the extant tropical forests. In turn, this will provide the key data necessary to determine the resilience of these forests to the future environmental challenges they face, and hence design the most effective strategies to help preserve them long into the future.

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Evolution and diversification of recalcitrant betel nut palms in South-East Asia

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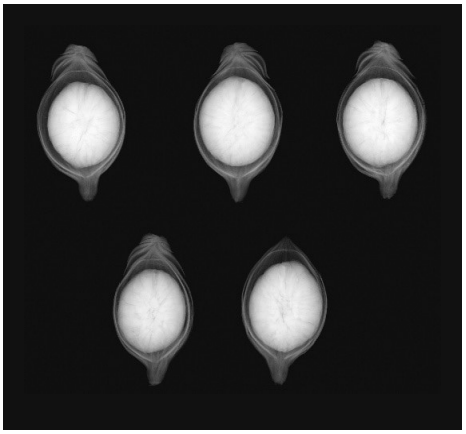
Palms (Arecaceae) can dominate tropical ecosystems in abundance or species number, they offer shelter and food to many animals, and the livelihoods of millions of people depend on their traditional or industrial use. They often occur in regions highly threatened by land use change, but the conservation status of most palms remains unknown, preventing actions to save threatened species. Palm seed banking is challenging because the seed storage behaviour of most species is unknown, although many are expected to have recalcitrant seeds. We also do not know how palm diversity evolves, for instance why palm seeds vary in size and shape, or how palms achieved their current distribution and what environmental factors constrain it.

As part of a global effort to improve our understanding, this project focused on the betel nut tribe (Areceae), which comprises 560 palm species in South-East Asia. We generated large genomic and seed trait datasets (>90% and >60%, respectively) of all Areceae species, using worldwide fresh and herbarium collections.

Research Assistant A. de Vries x-raying palm fruits at the Millennium Seed Bank.

The genomic data are now being analysed to determine the tree of life for tribe Areceae, which will feed into the global palm tree of life. Together with the seed data, this will provide an essential framework to facilitate future research on palm seed biology. In parallel, we are using the data to develop tools to monitor and conserve palms, for instance DNA barcodes to identify palms in manufactured products, and machine learning to identify threatened palms and important palm areas with high diversity.



Photos: A. de Vries

Fruit x-rays: a non-destructive method to access information from historical collections.

ACKNOWLEDGEMENTS / REFERENCES:

Additional support which enabled this work was kindly provided at RBG Kew by Dr John Dickie, Janet Terry, Pablo Gomez Barreiro, Laszlo Csiba and Robyn Cowan.

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How common is slow germination in Caribbean palms?

ANNE M. VISSCHER (Career Development Fellow, Comparative Seed Biology, RBG Kew), ELENA CASTILLO-LORENZO (former Research Fellow, Comparative Seed Biology), PETER TOOROP (former Research Fellow, Comparative Seed Biology) & HUGH W. PRITCHARD (Senior Research Leader, Comparative Seed Biology, RBG Kew)

Seed form and function reflect evolutionary trajectory and ecological competitiveness. This is especially the case in palms (Bellot et al., 2020), as the presence of a thick endocarp and relatively small embryo potentially combine to hinder germination efficiency under a changing climate (Batista et al., 2016).

We aimed to understand how common slow germination is in a range of species from the genera *Carpentaria, Coccothrinax, Dypsis, Livistona, Phoenix*, *Pseudophoenix, Ptychosperma, Roystonea, Sabal, Thrinax* and *Washingtonia*. Our primary focus was on palms of the Dominican Republic, which we compared with other palms available as seed in the commercial trade or from living collections.

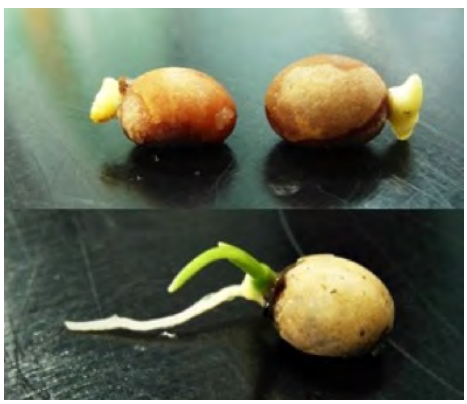

Photo: Elena Castillo-Lorenzo

Healthy seedlings of *Roystonea borinquena.*

Cleaned seeds varied in weight about 50-fold, from c. 100 mg to c. 5 g each. A temperature of 30°C tended to be acceptable for seed germination, although we found considerable inter-species differences in the times to germinate, from around 10 to >100 days. The degree to which this variability reflects differences in the biomechanical properties of the endocarp is of interest.

Some seeds germinated poorly at cooler temperatures, including the tropical palm *Pseudophoenix ekmanii*. Using a transcriptomics approach (with oil palm as the reference genome), we found that seeds of this threatened species have enhanced expression of genes related to inhibition of germination when sown at cooler temperatures (Visscher et al., 2020).

We conclude that the considerable heterogeneity in palm seed germination provides a framework within which to dissect the physical, physiological and molecular parameters that influence the developmental switch from the non-germinated to the germinating state.

ACKNOWLEDGEMENTS / REFERENCES:

Additional support was provided by the Dr. Rafael Ma. Moscoso Jardín Botánico Nacional in Santo Domingo, Dominican Republic and CAPES, Brazil.

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Seeds collected from Critically Endangered *Calophyllum africanum*

XANDER VAN DER BURGT (Curator and Field Officer, Identification and Naming, RBG Kew)

Calophyllum africanum Cheek & Q.Luke (Clusiaceae) was described in 2016, using fruiting herbarium collections from a single site in Mali, near the border with Guinea. The species is assessed as Critically Endangered on the IUCN Red List because only eight mature trees were found, within the area of a proposed uranium mine.

In 2019, during work for the Global Tree Seed Bank Programme (GTSBP), a team of seed collectors from Guinea and RBG Kew found *Calophyllum africanum* trees in three sites in Guinea, at 200 km, 320 km and 460 km from the type locality in Mali. A total of 195 mature trees were found on rocky ground along fast-flowing streams.

Seeds of *Calophyllum africanum* were collected in one of the three Guinean sites and stored at Kew's Millennium Seed Bank. Flowers were also collected – the first flowering collection ever made of this species. As well as enabling a seed collection to be made, the GTSBP also led to a substantial increase in knowledge on the distribution, ecology and taxonomy of this rare tree species.

Photos: Xander van der Burgt

A flowering branch of *Calophyllum africanum* on Mt Tibe in Guinea. At this site, the first flowering herbarium collection was made.

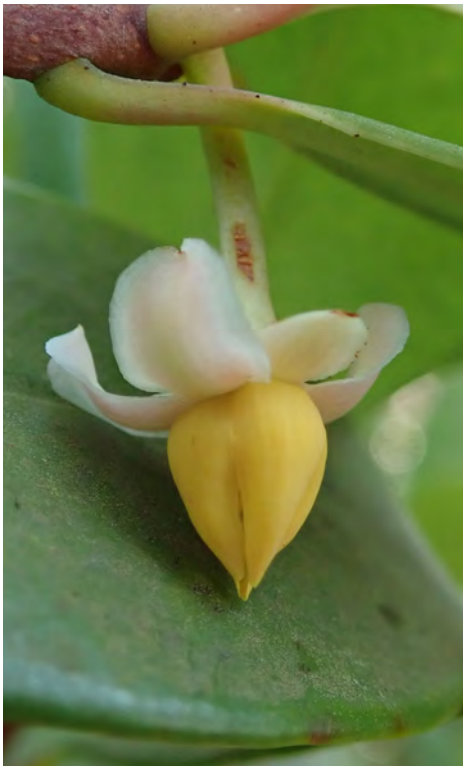
Distribution of *Calophyllum africanum*. The blue dot is the type locality of the species in Mali; the three red dots are the localities in Guinea where the species was found by the team of seed collectors from Guinea and Kew.

Map: simplemappr.net

Ripe fruits of *Calophyllum africanum* at the Dinkon waterfall in Guinea. At this site, seeds were collected for Kew's Millennium Seed Bank.

A rare new tree species discovered in Guinea: *Ternstroemia guineensis*

XANDER VAN DER BURGT (Curator and Field Officer, Identification and Naming, RBG Kew)



Photos: Xander van der Burgt

A flower of *Ternstroemia guineensis*. Flowers were the first to be collected from this species; on later expeditions, fruits and seeds were also collected.

In 2017, during work for the Global Tree Seed Bank Programme (GTSBP), a team of seed collectors from Guinea and RBG Kew collected flowers from a group of unidentified shrubs and trees on the southern Kounounkan Plateau, an uninhabited, 1,180-metre-high table mountain in Guinea. Back in the UK, Martin Cheek from Kew's Africa team determined that the flowering collection was a new species in the genus Ternstroemia.

The team returned to the same group of trees in 2019, to collect fruits. *Ternstroemia guineensis* Cheek (Ternstroemiaceae) was described in 2019, using the flowering and fruiting herbarium collections.

The new species is assessed as Endangered according to IUCN Red List criteria, because it is found only on a single table mountain, where 169 mature shrubs and trees were counted along four seasonal streams. The largest tree is 9 m high.

Ternstroemia species are distributed in tropical and subtropical regions in Africa, Asia and America; this is the first species from West Africa. Seeds of *Ternstroemia guineensis* were also collected in 2019 and stored in Kew's Millennium Seed Bank. As well as numerous seed collections of rare tree species, the GTSBP also enabled the discovery of several new plant species in Guinea.

Fruits of *Ternstroemia guineensis*. These fruits are not yet ripe, but a month later ripe seeds could be collected.

Seeds of *Ternstroemia guineensis*. These seeds were collected for Kew's Millennium Seed Bank.

Caribbean gems in the bank

THOMAS HELLER (RBG Kew), JEANINE VÉLEZ & BÁRBARA SÁNCHEZ (University of Puerto Rico, Mayagüez), JOSÉ SUSTACHE & CIELO FIGUEROLA (Puerto Rico Department of Natural and Environmental Resources), TAVIS WEEKES (Montserrat Department of Environment), INGERIA MILLER (Bahamas Forestry Unit), NATASHA HARRIGAN (National Parks Trust of the Virgin Islands), ALFRED PROSPERE (St Lucia Department of Agriculture, Fisheries, Natural Resources and Co-operatives)

The Global Tree Seed Bank Programme (GTSBP) in the Caribbean engaged with partners across several countries and territories: Puerto Rico, the Bahamas, St Lucia, the British Virgin Islands, Montserrat and the Turks and Caicos Islands (activities in the Dominican Republic were managed as a separate component of the wider project).

As a global biodiversity hotspot with almost 8,000 taxa (at species level or below) endemic to the region, the Caribbean islands represent an important focus for targeted seed collecting for conservation. During the programme, 120 tree and shrub species were collected and banked. Here we highlight a few species of particular interest:

***A) Plumeria krugii* (Apocynaceae)**

An attractive species with showy flowers, this species is endemic to Puerto Rico, and is likely to be Endangered according to IUCN criteria. Collected from Maricao by the team from the University of Puerto Rico, this species was severely impacted by Hurricane Maria in 2017.

***B) Thouinia striata* var. *portoricensis* (Sapindaceae)**

One of two endemic varieties of *Thouinia striata,* var. *portoricensis* is a rare tree of south-western Puerto Rico. Collected by staff from the Department of Natural and Environmental Resources, this plant would be categorised as Vulnerable using IUCN criteria.

***C) Miconia furfuracea* (Melastomataceae)**

Joint fieldwork by Kew and the St Lucia Department of Agriculture, Fisheries, Natural Resources and Co-operatives in November 2018 resulted in the first collections of seed from this Eastern Caribbean nation to be banked by the Millennium Seed Bank Partnership. *Miconia furfuracea* is restricted to Dominica, Martinique and St Lucia, and is found in lower montane rainforests on these islands.

***D) Juniperus barbadensis* var. *lucayana* (Cupressaceae)**

This gymnosperm, Red Listed as Vulnerable, is found only in the Bahamas, Cuba and Jamaica. The most extensive populations are found in the Bahamas, though populations are under threat from habitat loss. Seeds were collected by the Bahamas Government's Forestry Unit and are now secure at the Millennium Seed Bank. The typical variety, var. *barbadensis*, is found only on the summit of Petit Piton in St Lucia. With only about 50 wild individuals remaining, it is Critically Endangered. Attempts to collect seeds from cultivated plants failed to yield viable seed, so it remains a high priority for seed conservation.

***E) Solanum conocarpum* (Solanaceae)**

Until recently, this shrub was thought to be endemic to the island of St John in the US Virgin Islands, where fewer than 200 plants are known in the wild. Joint fieldwork between teams from the National Parks Trust of the Virgin Islands and Kew revealed a population of the species on Tortola in the British Virgin Islands, a significant discovery. Seeds and vegetative cuttings were collected by the Trust, securing this species in *ex situ* collections.

***F) Rondeletia buxifolia* (Rubiaceae)**

Though seed of this Critically Endangered shrub has been banked previously, fieldwork for the GTSBP led to the discovery of plants east of Montserrat's Centre Hills, an increase to the extent of the previously known population. Seeds from these plants were collected in 2018 by staff from the Montserrat Department of Environment.

A) *Plumeria krugii*

B) *Thouinia striata* var. *portoricensis*

C) *Miconia furfuracea*

D) *Juniperus barbadensis* var. *lucayana*

E) *Solanum conocarpum*

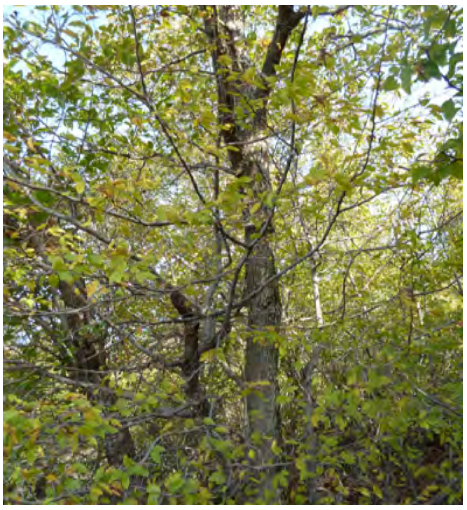
F) *Rondeletia buxifolia*

Photos: Jeanine Vélez / Cielo Figuerola / Thomas Heller

Species Study: Field elm (*Ulmus minor* Mill.)

DAVID KIKODZE (Deputy Director, Institute of Botany, Ilia State University, Georgia)

Photos: Konstantine Kereselidze



Ulmus minor on the edge of woodland near Shiomghvime monastery, Mtskheta municipality, Mtskheta-Mtianeti region.

Ulmus minor in fruit, near Telavi city, Kakheti region.

Field elm is a deciduous tree up to 30 m tall. It is characterized by dark grey, glabrous bark and long-petiolate, ovate or obovate serrate leaves with an oblique base. The fruit is an obovoid glabrous samara. This tree grows in oak woods, forest margins and riversides up to 800 m above sea level, both in eastern and western Georgia.

The Georgian populations of field elm were impacted by Dutch elm disease and continue to decline. To prevent additional human-induced disturbance such as felling, habitat loss and fragmentation it was decided to protect the species by including it in the Georgian Red List.

Colombia's tropical dry forest still has a lot to offer

JENIFFER DÍAZ (Alexander von Humboldt Institute, Colombia)

Libidibia punctata (syn *Caesalpinia ebano*) is a characteristic species of Colombia's most threatened ecosystem, the Caribbean dry coast. The species has hard wood, is heavy and black in colour and is easy to polish – it is therefore used in the manufacture of handicrafts. Due to logging, *L. punctata* is endangered. There are a few individuals in protected areas, but these are of unknown number. The seed of this species was collected in Parque Nacional Natural (PNN) Los Colorados from two individuals.

It was difficult to find because the species prefers undisturbed areas within mature forests. In the local seed bank, there are now 4,013 seeds protected. 'Pipilongo' is the vernacular name for this species among the community of Robles in Jamundí, Cauca Valley.

Piper tuberculatum is very important for the culture and economy in this region because it is recognised as a native substitute for black pepper (García, 1974). It is also useful in restoration programmes as an intermediate pioneer species, so it's important to start establishing the species in disturbed areas.

Piper tuberculatum was collected in San Jacinto from seven individuals, in an area of secondary forest. There are 7,364 seeds conserved in the seed bank. There are approximately 2,600 species of plant in this ecosystem – that's 2,600 reasons why the conservation of this ecosystem should be prioritised. We already have 94 of those reasons in the seed bank… One seed at a time!

The forest gives us art…

Libidibia punctata (Willd.) Britton. Regional distribution: Caribbean plain. Native, Endangered.

The forest spices up life…

Piper tuberculatum Jacq. Regional distribution: Amazonas, Andes, Caribbean plain, Orinoquia, Pacífico, Cauca Valley, Magdalena Valley. Native, Least Concern.

Photos: Sofía Garzón / Jeniffer Díaz

Libidibia punctata (Caesalpinia ebano). The image shows material collected for a herbarium voucher with leaves and fruit.

Piper tuberculatum. The image above shows the amento (catkin).

A mature tree of *Libidibia punctata* (*Caesalpinia ebano*).

Piper tuberculatum. The image shows a difference in maturity of the amento (catkin), from inflorescence on the left to immature infructescence in the centre and mature infructescence on the right.

Colombia moving forward – has the Global Tree Seed Bank Programme influenced future plans?

AMALIA DÍAZ (Alexander von Humboldt Institute, Colombia)

Photo: Carolina Castellanos

Fieldwork in PNN Los Colorados, San Juan Nepomuceno.

The Global Tree Seed Bank Programme has provided us with a new perspective on seed banking, and a powerful resource to widen both our botanical collections and their uses. We have identified three main areas of future action:

1. Seed banking of native plants of economic importance: In Colombia, where most of its wealth lies in its biodiversity, useful plants are a key factor in economic development, and seed banking is an important resource. We are participating in a multidisciplinary project which aims to find native plants with potential as a food source. Our seed bank here is essential, since it represents the first step in the domestication of such plants.

2. Strengthen relationships with botanic gardens: Several aspects of the ex situ conservation of native plants require collaboration. This is especially true in tropical areas with high plant diversity and where resources are often limited. Botanic gardens are leaders in plant conservation, so creating alliances with other seed banks can help to facilitate the long-term conservation of threatened and endemic species. In order to strengthen our bonds with local and regional botanic gardens and highlight opportunities as members of the Millennium Seed Bank Partnership, we participated in the First Regional Workshop of South American Botanic Gardens, organised by BGCI (Botanic Gardens Conservation International), in Colombia, in October 2019.

3. Local dissemination of knowledge: One of our main strengths is the people in which the project has invested heavily. The project provided the current level of training and expertise to our personnel and interns, who are an invaluable resource for outreach activities and dissemination of knowledge among the scientific and non-scientific public. We have participated in a programme of open talks, a workshop directed at curators of other local, small natural history collections, and with the help of one of our interns, we are developing an atlas of seeds of the tropical dry forest. Currently, with funds from the Garfield Weston Foundation, we are also working on the publication of a manual on seed banking and conservation of native plants.

Seeds for the future - Global Tree Seed Bank Programme in the next phase

SHARON BALDING (Seed Conservation Projects Officer, RBG Kew)

Following the success of the Global Tree Seed Bank Programme (GTSBP) from 2015 to 2019, funding for a new phase was awarded by the Garfield Weston Foundation, to begin in January 2020 for three years. In this new phase, five of the projects represent established partnerships from the previous programme, allowing us to build on activities and achievements in Mexico, Madagascar, Bhutan, Thailand and Indonesia. In addition, three new projects have been developed in Mozambique, South Africa and Pakistan, with existing Kew partners in countries with large numbers of threatened tree species not yet banked.

Complementing the new seed collecting activity are research projects and species conservation assessments to be carried out by in-country projects and at Kew. Based at the Millennium Seed Bank (MSB) and within the Comparative Seed Biology team, a new research project will soon begin, called 'IMproving the PREservation of difficult-to-store Tree Seeds' – IMPRETS. This research will improve understanding of tree seed form and function and the application of low temperature science to the preservation of tree seeds. Elsewhere, for example in Mexico, the research aims to support reforestation activities using seeds of native tree species important for the livelihoods of local communities.

Photo: Naomi Carvey

Participants of the Global Tree Seed Bank Programme attending a training course at Cibodas Botanic Garden, Indonesia, in 2017.

The new programme also has a substantial training and capacity building element to strengthen partner organisations' long-term capacity to carry out seed conservation work. This includes investment in the MSB's Seed Conservation Techniques course, as well as providing online training resources to a wider conservation community, particularly in a post COVID-19 world.

For more information on the GTSBP, please contact sharon.balding@kew.org

UK tree seed conservation at the MSB

ALICE HUDSON (former UK National Tree Seed Project Officer)

Only 13% of the United Kingdom's land area is wooded, with just 2% covered by ancient woodland (continuously wooded since 1600 AD in England and Wales, and 1750 AD in Scotland) (POST, 2014). This habitat is under increasing threat due to the combined influences of climate change, pests/diseases and land-use change.

Prior to 2013, the Millennium Seed Bank (MSB) held on average three collections per species for the common UK woody species with orthodox seeds. Given the broad range of threats (in particular the 2012 arrival of ash dieback disease) and the importance of genetic diversity in enabling a species to adapt and respond to these threats, there was increasing need to capture a greater level of genetic diversity within the MSB's UK tree seed collections. This led to the launch of the UK National Tree Seed Project (UKNTSP) in 2013 funded by players of People's Postcode Lottery.

This was the first seed-collecting project at the MSB to specifically focus on multi-provenance, genetically representative seed collecting, where seeds would be stored, as far as possible, by individual georeferenced maternal trees. The project used the Forestry Commission seed zone map as a sampling framework, aiming to make one seed collection for each target species, in each seed zone it was considered native, above and below 300 m altitude. This resulted in 936 possible targets across 76 species.

Photo: S. Miles / Hannah Fraser / Katie Thorpe

Collecting lime.

Table 1: Example of collections held for six UKNTSP species

Species	Number of collections	Average number of maternal plants per collection	% >300 m targets met	% <300 m targets met
Fraxinus excelsior	83	8.5	50	100
Ilex aquifolium	64	6.8	75	100
Torminalis glaberrima	22	3.6	N/A	70
Sambucus nigra	49	8.5	50	100
Corylus avellana	37	22.2	17	75
Betula pubescens	58	8.2	53	100

The UKNTSP ran from 2013 to 2020, during which time more than 1,300 seed collections were received. Around 80% of these were made by partner organisations. Combined with pre-UKNTSP collections, the MSB now holds collections towards 73% of the 936 targets, averaging 18 collections per species (for a summary of collections held, see Table 1).

The scale of this project and its achievements would not have been possible without the help of more than 30 partner organisations across the UK, who undertook seed collecting with their volunteer groups. In 2019 alone, more than 110 volunteers were involved with the project. The UKNTSP also focused on research to overcome several challenges to the *ex situ* conservation of UK tree seed.

This included research into the effectiveness of the sampling strategy in capturing genetic diversity, ensuring reliable germination protocols for target species and investigating protocols for species with short-lived seeds. For example:

- A genetic investigation of *Taxus baccata* collections revealed that 86% of the alleles found in the maternal trees were also present in the seed collections sampled (Gargiulo et al., 2019).
- We trialled banking Salicaceae seed (known to be short-lived) on a UK wide scale. From 2018 to 2020, over 70 Salicaceae collections were banked.

Euonymus europaeus collection.

Collecting hawthorn.

The UKNTSP represents a major step towards the *ex situ* conservation of the UK's woody flora, but what about the future? Climate change is likely to place increasing pressure on the upland flora (Trivedi et al., 2008), yet fewer of the collecting targets above 300 m were met compared to those below 300 m. Although this is in part likely due to fewer woodlands above 300 m meeting the sampling criteria for the UKNTSP, increased focus should be placed on sampling from priority upland areas.

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Conserving 'the beauty berry' across the Malesian floristic region

CAMILLA ARVIDSSON (Science undergraduate intern, RBG Kew)

Known as 'the beauty berry', *Callicarpa,* a genus of the Lamiaceae family, includes approximately 140 species globally. Occurring in both temperate and tropical regions as shrubs or small trees, they are famously cultivated for their beautiful fruit (Bramley, 2019).

Temperate species, such as *Callicarpa americana*, can be found in the gardens at Kew, but it is the 55 tropical, Malesian species that are of interest to the Plant Assessment Unit (PAU) in the Herbarium. In the PAU we assess the extinction risk of species for the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. These assessments are paramount as they are used to both inform and catalyse action for biodiversity conservation and policy change. Unfortunately, 40% of the 55 Malesian *Callicarpa* species assessed were identified as threatened, with habitat loss listed as the major threat.

Common across South-East Asia, this is due to the increasing conversion of forested habitats into agricultural land as population levels increase. Logging, mining and urban growth were also identified as causes of significant habitat loss. The first step in helping to conserve and save *Callicarpa*, and any threatened tree species, is to identify their distribution and sources of threat. For Malesian *Callicarpa*, this has been achieved.

However, plant species are significantly under-represented on the IUCN Red List of Threatened Species. Fortunately, dedicated scientists from Kew and across the world are working to change this. Co-ordinated by Botanic Gardens Conservation International, the Global Tree Assessment project looks set to complete its assessments of all trees by early 2021, a fantastic boost for plant conservation worldwide.

With thanks to the Toyota Motor Corporation which funds the Plant Assessment Unit at Kew.

Callicarpa pentandra tree.

Callicarpa hispida close-up.

Photos: Dr Gemma Bramley

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Conservation of Ghana's rare, threatened and economically important woody species

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Photos: CSIR-FORIG National Tree Seed Centre

Good Voucher Material: The Ghana FORIG Seed Centre team discussing the importance of good voucher material for their seed collection. (L-R) Mr Jonathan Dabo, FORIG Herbarium taxonomist; Mr Tim Pearce, RBG Kew; Dr Joseph Asomaning, FORIG Senior Researcher; Mr James Amponsah, FORIG Seed Research Scientist; Professor Gabriel Ameka, University of Ghana.

With an annual forest cover loss approaching 2%, the challenges facing the conservation of Ghana's trees are some of the toughest across the continent, with inevitable impacts on soil, climate mitigation and food security. While we welcome initiatives such as the enactment of laws and a ban on the exploitation of many threatened species, international collaborations such as the Millennium Seed Bank Programme (MSBP) continue to offer immense assistance in safeguarding Ghana's plant genetic resources.

CSIR-FORIG has participated in collaborative projects through the MSBP since 2004. Our sister agricultural gene bank (CSIR-Plant Genetic Resources Research Institute) also joined the landmark Adapting Agriculture to Climate Change project. We continue this collaboration with a new partner, the National Herbarium based at the University of Ghana Botany Department. Our colleagues are working hard to digitise and georeference voucher specimen collections from Ghana's indigenous woody plant species. From this, the National Tree Seed Centre will lead the charge to collect and conserve seeds from at least 500 of the country's most threatened tree species funded by players of People's Postcode Lottery. A seed laboratory has been established at CSIR-FORIG, and this project will also help us install a much-needed dry room. So far, a prioritisation exercise has identified at least 50% of those species we intend to survey and collect. The project has already delivered some major outputs, by collecting and processing over 80 seed collections of some 75 species. These include economically important and threatened species listed on the IUCN Red List. The need to accelerate the *ex situ* conservation of Ghana's most threatened and economically important species cannot be overemphasised. This project, focusing on the collection and conservation of Ghana's woody species, has the potential to be the largest such project in the country's history.

Emmanuel (the Tree Climber) climbing a tree to collect seeds from the crown.

New MSB partnerships

Country/ territory	Counterpart Name/partnership	Start	Duration (Years)
Slovakia	Plant Science and Biodiversity Centre, Slovak Academy of Sciences (PSBCSAS)	March 19	3.5
Romania	Institute of Biological Research Cluj-Napoca (ICB), National Institute for Research and Development in Biological Sciences	March 19	3.5
Romania	Alexandru Borza Botanical Garden, Babeş-Bolyai University (UBB)	March 19	3.5
Poland	W. Szafer Institute of Botany, Polish Academy of Sciences (IB PAS)	March 19	3.5
Czech Republic	Herbarium and Department of Botany, Charles University (DBCU)	March 19	3.5
France	Centre National de la Recherche Scientifique (CNRS) on behalf of Laboratoire d'Ecologie Alpine (LECA), Université Grenoble Alpes	March 19	3.5
Thailand	National Science and Technology Development Agency	May 19	5

Key science publications

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Ballesteros, D., Pence, V.C. (2019). Survival and growth of embryo axes of temperate trees after two decades of cryo-storage. *Cryobiology*, 88, 110–113.

Blandino, C., Fernández-Pascual, E., Marin, M., Vernet, A., Pritchard, H.W. (2019). Seed ecology of the geophyte *Conopodium majus* (Apiaceae), indicator species of ancient woodland understories and oligotrophic meadows. *Plant Biol (Stuttg)*, 21(3), 487–497.

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Seed Conservation Techniques training course 2020

We are delighted to announce that the MSB's popular Seed Conservation Techniques (SCT) training course will be running this autumn. Following the Partnership's agreed Seed Conservation Standards, the course provides trainees with the knowledge needed to collect, conserve and manage high quality *ex situ* collections of wild plant seeds. Topics covered will include: planning a seed collection programme, assessing and collecting techniques, post-harvest handling, measuring seed moisture content, seed processing and quality assessment, and seed germination and dormancy. Given the ongoing COVID-19 pandemic the course will look and feel a little different this year, with many of the modules being offered online in November, followed by a practical, laboratory and field-based course once travel and social distancing restrictions are lifted.

To register your interest in the course, please contact the training coordinator, Hanna Oldfield, at h.oldfield@kew.org.

MSB Dashboard	5 May 2020
Total Collections	96,119
Total countries (including overseas territories)	190
Total families	351
Total genera	6,166
Total species	39,841
# of good seeds	2,357,843,896
Collections despatched	11,872

Next issue

Issue 36 of Samara will be a special edition to mark the 20th anniversary of the Millennium Seed Bank in 2020. As a community we would very much like to hear from you as MSB Partners with stories either relating to how seed conservation has changed and developed over the past two decades, recollections of notable collaborations within the Partnership over the last twenty years, or how you see the partnership growing and developing in the coming years. If you have a story that you would like to contribute, please contact our editorial team – we would love to hear from you.

We want to hear from you!

Samara is your newsletter so please send us any articles you feel would be of interest to the MSBP.

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Samara provides information and inspiration for MSBP partners and a flavour of the successes of the Partnership. It is available as a PDF from the MSBP website at **brahmsonline.kew.org/msbp/Training/Samara**