

Royal Botanic Gardens

Kew

The Weston Global Tree Seed Bank

End of Phase 3 report

January 2024

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Executive Summary

Since its inception in 2015, the Weston Global Tree Seed Bank (GTSB) project, generously funded by the Garfield Weston Foundation, has brought together partner organisations in 41 countries and territories across the world to conserve the rarest, most threatened and useful trees. It has also enabled Kew to conduct research to fill vital gaps in our knowledge of tree conservation. In 2019, a further grant was awarded by Garfield Weston enabling a three-year project which began in January 2020 with the aim of conserving up to 2,000 tree species from extinction in eight countries and training 45 scientists in seed banking techniques.

At the end of 2023, we successfully completed Phase 3 of the programme. This end of Phase 3 report reflects the amazing depth and breadth of work, and achievements across the eight partner countries and associated research projects. We outline progress during 2023 and over the course of the programme.

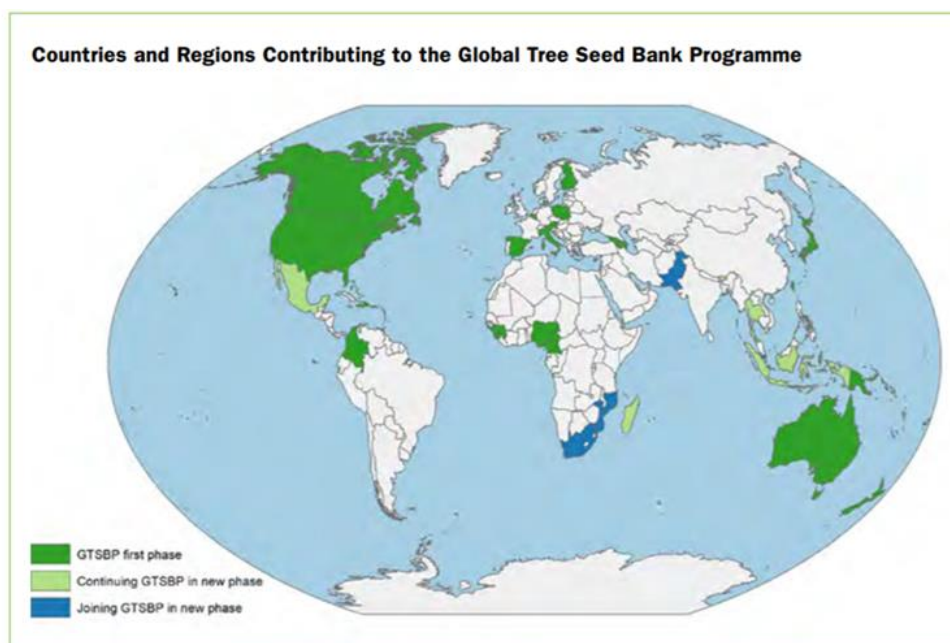
Project Background

In this phase, five of the projects represented established partnerships from previous phases of the programme, allowing us to build on activities and achievements in Mexico, Madagascar, Bhutan, Thailand and Indonesia. In addition, three new projects were developed in Mozambique, South Africa and Pakistan with existing Kew partners in countries with large numbers of threatened tree species not yet banked.

Complementing seed collecting activity were research projects and species conservation assessments to be carried out by in-country projects and at Kew. The research project based at the Millennium Seed Bank (MSB) was called 'IMproving the PREservation of difficult-to-store Tree Seeds' – IMPRETS. This research aimed to 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, research aimed to support reforestation activities using seeds of native tree species important for the livelihoods of local communities. The programme also had a substantial training and capacity building element to strengthen partner organisations' long-term capacity to carry out seed conservation.

The major planned outcomes for this phase of the project were as follows:

1. Collect, bank and research up to 2,000 of the world's rarest, most endangered and most useful tree species, saving them from extinction.
2. In-country capacity building: investing in essential infrastructure, equipment and data sharing to improve our partner organisations' long-term capacity to carry out seed conservation work.
3. Seed Conservation Techniques courses: over three years, these three-week courses will train 45 scientists on targeting, collecting, processing, testing and using seeds according to the MSB Partnership published standards. These will be delivered both at Kew and in partner countries.
4. Online resources: Training videos will be made available online as well as Seed Conservation Technical Information Sheets and web materials. This will enable knowledge and skills to be shared with a wider scientific community.



Summary

Despite a challenging and delayed start due to the impact of the Covid pandemic, Phase 3 of the Weston Global Tree Seed Bank has been hugely successful. Over the course of the programme, Kew and our partners have **made 2,475 collections from 1,736 threatened and/or useful tree species across eight countries**. These collections are now stored in in-country seed banks with many duplicated to the Millennium Seed Bank, saving them from extinction.

The species conserved include Critically Endangered species such as the *Psyrdrax sambiranensis* from Madagascar and *Brackenridghea zanguebarica* in South Africa. Seed from **economically important and useful woody species** were also collected, for example *Ziziphus oxyphylla* from Pakistan which is used for traditional treatment of different ailments including jaundice, *Greyia radkoferi* from South Africa which is used by local communities to make household utensils and for carving handicrafts, and the Near Threatened *Curtisa dentata*, also from South Africa, which is exploited for timber and its bark is harvested for traditional medicine. IUCN Red List assessments are vital in helping us to evaluate the extinction risk of species and subsequently prioritise conservation actions. Over the course of the programme, 319 assessments have been produced.

Phase 3 of the Weston Global Tree Seed Bank has significantly improved the capacity of our partners to carry out seed conservation work. There is a huge variety between countries in terms of capacity, research facilities and resources available to our partner institutions. No matter the baseline, **significant progress has been made towards enhancing capacity at our partner institutions**. A key example includes a new drying room in Madagascar to enhance the ability of the national seed bank there to process and store good quality seed collections. The GTSB programme has also inspired the development of a new seed bank in Thailand.

We have also improved capacity by delivering training to our partners. In total, **64 people participated in our Seed Conservation Techniques courses**, equipping scientists with the knowledge, understanding and skills they need to collect, conserve and manage seed collections in their own country. During the programme, we have seen participants sharing their knowledge with their peers, and participants on in country SCT courses then becoming trainers on subsequent courses. **Online resources** have also been made available via the [Training](#) and [Resources](#) pages of our project website. Overall, this project leaves an important legacy of knowledge in **more than 300 participants of training** that can contribute to the conservation of trees and nature across the world.

The programme has enabled us to increase our understanding of tree seed form and function through our IMPRETS research project, with 747 seed collections assessed. We look forward to publishing the results later in the year. Phase 3 has supported reforestation activities in Madagascar, Indonesia and in Mexico where 75,000 trees have been propagated, over half of which have been donated to local communities or used in reforestation trials, with the rest being donated later this year.

In addition to the above activities, the team have worked hard to bring the programme to a close and ensure the sustainability of their efforts in four partner countries where, for now, this represents the end of their journey with the Global Tree Seed Bank.

We look forward to continuing our work in the next phase, the Weston Global Tree Seed Bank: Unlocked.



Seed collections and herbarium specimens in Mexico and the end of project workshop in Bhutan.

Project Progress

Madagascar

Madagascar remains an important focus for conservation. At least 60% of tree species in Madagascar are threatened with extinction (Beech et al., 2020). The flora is estimated to total over 12,000 flowering plant species, of which over 90% are endemic. There are 5 endemic families and over 300 endemic genera, making Madagascar a top 10 global biodiversity hotspot. The Global Tree Seed Bank in Madagascar plays a crucial role in the preservation of the country's biodiversity. The programme is conducted in collaboration with our Malagasy partner Silo National des Graines Forestières (SNGF), with the primary objective of collecting and safeguarding some of the rarest, most endangered, and economically valuable tree species found in Madagascar.

Summary of progress

The KMCC team along with their colleagues at SNGF exceeded their collecting targets for 2023 and for the programme as a whole, making an incredible 721 collections against their target of 450, made up of 391 species, against their target of 300. These collections came from across 18 different regions of Madagascar each with a particular vegetation type, and from 77 different families and 210 genera. Remarkably 14 of these species are thought to be new discoveries – this will be confirmed once the herbarium vouchers have been studied.

25% of the species collected are classed as threatened according to the IUCN Red List. Notable endangered taxa collected include various species of *Dalbergia* which are all exploited for their valuable timber – *Dalbergia* remains one of the most widely trafficked natural products – and various species of *Adansonia* – the iconic Baobab whose fruits are a delicacy and so the genus faces exploitation from over-collection among other threats.



SNGF technicians cleaning seed collections

The project in Madagascar has involved digitising herbarium vouchers of all collections held at SNGF, to aid identification and increase access to information about the Malagasy flora. The team will continue this work under the next phase of the programme. The team have been working on improving a digital tool to automate Red List assessments, and 4,300 trees and shrubs either now have a Red List status, or a predicted status. Another digital platform utilised and improved under this project is the i-Naturalist platform – the team uploaded almost 4,600 observations during the life of the project.

June 2023 saw the inaugural Seed Conservation Techniques (SCT) course in Madagascar held at SNGF, providing training and technical advice to build the capacity of SNGF and the MSBP team in Madagascar to collect, store and manage high quality seed collections - 18 participants attended. During the year, the project invested in a new drying room at SNGF, greatly developing their capacity to process and store good quality seed collections.

Mozambique

Amongst the poorest countries in the world, more than 75% of its population is engaged in rural agriculture. Forest currently covers nearly a quarter of the country, but woodland is being rapidly converted to agricultural use to meet the needs of the growing population. Biodiversity hotspots are also increasingly threatened by mining activity and extensive oil exploration. For this project we worked in partnership with Mozambique's Agricultural Research Institute (IIAM) on the Mozambican National Seed Conservation Programme, to strengthen the capacity of the national seed bank housed at IIAM and provide duplicates of tree seed collections to be stored at the Millennium Seed Bank in the UK.

Summary of progress

The GTSB project has been a key part of the National Seed Conservation Programme over the last three years, enabling the team to carry out fieldwork and research, contributing to understanding and conserving Mozambique's tree species. The IIAM MSBP team exceeded their overall GTSB seed collections target of 240 collections, making 244 seed collections by December 2023, and were also close to meeting their species target, collecting 195 species from their target of 240 species, despite facing huge challenges. Their seed collections include seven threatened species, 21 endemic or near-endemic species and 98 useful species. Notable collections include an endemic tree that is used locally for its timber, *Millettia mossambicensis*, and an important native edible fruit tree species, *Strychnos spinosa*.

Following the Seed Conservation Techniques course in November 2022, which focussed on training a national network of IIAM seed collectors, the IIAM MSBP team equipped their network teams with field camping and seed collecting equipment and worked with them to identify target species in their regions and plan their fieldwork. The five network teams completed their first seed collecting expeditions in July, with subsequent expeditions in October, significantly increasing the seed collection rate for the programme. The IIAM MSBP team are monitoring the seed collection and data quality and providing continued support and training for their network collectors.

Training and research visits to the UK provided some of the year's highlights for the IIAM MSBP team. Cacilda Manhiça, the Senior Seed Conservation Officer and Project Coordinator, attended Kew's two-week Tropical Plant Identification course in May and completed a five-week research visit to the MSB in November. During the research visit Cacilda investigated the seed viability of four useful native tree species from Mozambique as a basis for an ongoing research collaboration to understand their long-term seed storage behaviour. In addition, Joelma Souane, the Herbarium Digitisation Officer, attended a two-week data training visit to the MSB, to work with the Kew project lead, to develop the team's data management strategy.



Cacilda Manhiça, researching seed behaviour at the MSB using Mozambican native species

The IIAM MSBP team faces a challenge in setting up their long-term seed storage facility, due to frequent power cuts in Maputo. They are working to ensure that an existing backup generator and fuel supply is managed effectively to protect the valuable seed collections in their dry room and seed bank freezers. The duplicate collections sent for safe storage at the MSB provide a backup in case of damage to their facility.

Indonesia

In this phase of the programme, Kew along with the Indonesian National Research and Innovation Agency (BRIN, formerly LIPI) and the University of Bogor aimed to build on and expand the achievements of the previous phase. The objectives of this project were to collect and bank seed of a further 100 woody species; to complete plant conservation assessments of woody plant species and to support a PhD project on conservation risk and threats to the Indonesian tree flora, by an Indonesian student, co-supervised by Kew.

Summary of progress

The team from BRIN have been working towards collecting 100 bankable species for long term conservation, and 36 more to be grown in a newly established tree nursery at Kuningan Botanic Gardens, allowing for conservation of recalcitrant species. They have successfully collected 91 species across the programme lifetime, 23 of which are being grown on in the tree nursery. As BRIN is a data only partner, these collections will only be banked in Indonesia, with the collection data uploaded to Kew's Data Warehouse.

An agreement between the Research Centre for Plant Conservation, Botanic Gardens and Forestry, and Ciremai

National Park has been prepared, and excellent progress has been made with planning and implementing the field-based restoration trials at Mt Ciremai National Park in Western Java (this work will continue under the next phase). 3,439 seedlings have been grown in the nursery at Kuningan Botanic Garden, comprising 21 families, 24 genera and 28 species. One species is endemic to Java (*Pinanga javana* Blume), and one species is categorised as Endangered (*Dipterocarpus retusus* Blume). In November 2023, Kew's Project Lead visited the site to help set up the plots and provided training on conducting the pre-planting baseline site survey.

PhD student Risna Rosniati continued to make good progress with her project on 'Endemic tree conservation planning under the scenario of climate change and resilience'. She published her systematic review and visited Kew in December 2023. This visit resulted in further development of her methodology for modelling the distribution of Javan endemic tree species under different climate projects, scientific paper planning and coordination, species conservation assessment drafts, and widened networking with Kew's scientists. Risna also carried out another four Red List assessments, bringing the total for the project in Indonesia to 58, with 29 species having been classified as Vulnerable.



Project staff at Kuningan Botanic Garden nursery, with some of the seedlings prepared for the restoration trial.

Bhutan

Bhutan is a remote, mountainous country with high biodiversity: 5,500 plant species are so far recorded, including over 400 species of orchid and 46 species of Rhododendron. With many species not yet described by science, the true total may be closer to 8,000. 750 species are endemic to the Eastern Himalayas and over 100 are known only in Bhutan. The project worked with the National Biodiversity Centre of Bhutan (NBC) to collect 75 woody species; to complete IUCN Red List assessments for 100 woody species and conduct longevity testing on some of Bhutan's alpine species.

Summary of progress

Six seed collection expeditions were made during the reporting period. A project workshop took place in Thimphu, Bhutan in October 2023, focussing on the review of Red List assessments completed as part of the project. A 'gap analysis' of threatened species not in ex situ conservation was also carried out and nine woody species were identified as conservation priorities. Herbarium samples were also processed for transfer to Kew.

38 tree and shrub species were collected in Bhutan during 2023, bringing the total number of tree and shrub species collected during the project to 99 species, some 24 more than the original



project target. Species collected during the project include *Sorbus rinzenii* (pictured) which is currently classed as Endangered due to continued decline in habitat.

The team had to overcome difficulties in the field including navigating rugged terrain, transportation of equipment, and working around landslides and floods. A lack of literature on germination protocols and seed handling also proved challenging, as well as differences in flowering and fruiting seasons of species between localities, making predictions difficult.

During the year, 32 species (including 10 provisional) were added to the Red List, two of which are classed as threatened. Kew and NBC staff have drafted assessments of 82 species in total. Of these, five species were classified as threatened.

Pakistan

Pakistan is one of the most vulnerable countries in the world to climate change. A rapidly increasing livestock population is placing biodiversity under threat as forests are cleared for grazing, forests in northern Pakistan are rapidly diminishing because of deforestation while coastal areas, which have had rich reserves of mangrove forests, are also quickly disappearing. The collaboration between Kew and the Pakistan Bio-Resources Conservation Institute (BCI) (part of Pakistan's Agricultural Research Council (PARC)) has focused on the collection of the most important threatened medicinal woody species that provide human health-related services.

Summary of Progress

Expedition missions commenced in June 2023, focusing on north western areas of Pakistan. The team in Pakistan struggled with access to remote locations and suffered from vehicular failure during more than one of their collecting missions. Despite this they had a successful year with 32 tree and shrub species collected, bringing the total number of tree and shrub species collected during this phase to 108. During the lifetime of the project, 21 Red List assessments were carried out on Pakistani woody species.

The team collected seeds from useful species during the programme, including *Helicteris isora*, a good source of fibre with the fruit said to be medicinally important, *Juniperus excelsa* which is used for fuel and pencil-making and *Rhamnus pentapomica* which is used in traditional medicine and pharmacological studies have shown has anti-inflammatory properties. The team have been working on increasing understanding of seed storage behaviour of native species throughout the project and hope to follow on from their work on the GTSB by continuing this work, for example by further researching *Tecomella undulata*, an Endangered species used in the treatment of sores and abscesses, and in ayurvedic medicine. It is used for timber, making charcoal, and in woodworking due to its soft and durable qualities.



The Pakistan team in search of *Helicteris isora*

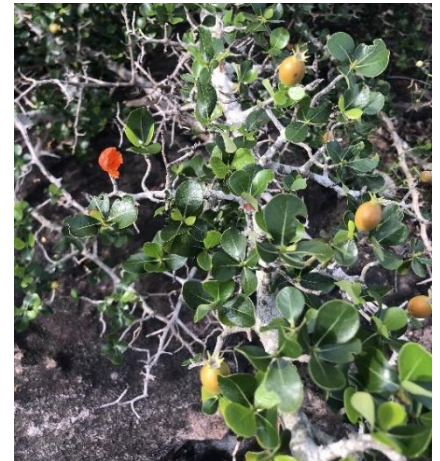
Thailand

Thailand lies at the meeting point of three floristic regions (Indo-Chinese, Malesian and Eastern Asiatic) and is home to a rich plant flora, estimated to include at least 10,000 vascular plant species, of which 756 are endemic. The floristic richness of Thailand and its surrounding area, coupled with a severe threat from unsustainable use and over-development, has led to the region being designated as a biodiversity hotspot. Working with Bangkok Forest Herbarium (BKF) and the Forest Restoration Research Unit, Chiang Mai University (FORRU-CMU), the main aims of the project in Thailand were to collect and bank seed of a further 300 mainly rare and endemic woody plant species and to complete plant conservation assessments for 225 woody plant species.

Summary of Progress

In 2023, 54 species were collected across Thailand, bringing the total number of Thai species collected during the programme to 164. The main challenges faced by the Thai team were relating to Covid induced delays to fieldwork and the process of obtaining permits which led to the occasional missing of peak fruiting periods and difficulty in accessing protected areas. BKF also reported that Thailand was affected by El niño in 2023 which may have caused drought and delay to flowering and fruiting times.

Species collected during the programme include the seeds of the shrub species *Gardenia saxatilis* (pictured) from the Chaiyakhum province, North-eastern Thailand. This species provides important habitat for wildlife, especially birds. Occurring on sandstone hill at 300-400m elevation, this species is threatened by habitat loss due to agriculture.



Staff from FORRU and BKF attended an end of programme workshop in Bangkok in November, to review Red List assessments carried out to date, carry out preliminary assessments on remaining species, carry out a 'gap analysis' of threatened species not in ex situ conservation and discuss publication of the results. A paper on developing a conservation plan utilising Red Listing data will be completed later this year. During the workshop, 160 assessments of endemic and near endemic Thai tree species were reviewed and 10 preliminary assessments completed. Over the course of the programme, Kew, FORRU, and BKF staff assessed a total of 216 species, highlighting 136 species that have been classed as threatened.

The GTSB programme has inspired the development of the FORRU seed bank – a regional seed bank developed specifically to support forest ecosystem restoration, seed research and education. This, in turn, has increased outreach to younger generations in tree species conservation. The seed bank has also provided opportunities for students and interns to develop projects around the seed collections. The collaboration with FORRU and BKF will continue under the next phase of the programme.



Staff from Kew and Thai partner institutes at end of project workshop in Bangkok, November 2023.

South Africa

South Africa is home to over 21,000 plant species with an extraordinary level of plant endemism at 67% and is one of the world's 17 mega-diverse countries. Sadly, 14% of South Africa's plant species are under threat of extinction. In South Africa, the project was part of an overall seed conservation programme to develop the national seed collection of South Africa. The partnership was with the South African National Biodiversity Institute (SANBI), which has a long history of working with the MSBP, going back over twenty years.

Summary of Progress

The South Africa team exceeded their overall species target of 396, making seed collections for a programme total of 456 species. These collections represent 43 threatened species, 219 endemic species and 106 useful species. Notable species collected in 2023 include *Curtisa dentata*, assessed as Near Threatened on the Red List. This tree is exploited for timber and its bark is harvested for traditional medicine.

Following SCT training in 2022, which included a focus on building germination testing capacity for the team, an active programme of germination testing is now underway. Initial germination tests on fresh seed provide a baseline germinability for monitoring the effects of drying and freezing on both short and long-term ex situ conservation. During 2023, the team provided seed germination training for South African students and interns. The team also have an active and successful outreach programme, regularly sharing their work with diverse audiences, with examples including participating in a Biodiversity Careers Day for schools and providing a three-day seed conservation training course for staff and interns at Harold Porter National Botanical Garden.



Collecting tree seeds during a trip to Kwazulu Natal in April 2023.

Project team member, Thembeke Malwane, attended a Cryopreservation training course at the MSB in October-November 2023. The purpose of the training was to provide trainees with the knowledge and understanding they need, to consider and apply different cryopreservation approaches for the ex situ conservation of plants. This was a valuable opportunity for Thembeke: *"This was an experience of a lifetime. With all that I learned I intend on imparting all that knowledge to my colleagues and use it towards making our own seed bank a state of the art seed bank, which will be a hub of knowledge and research for Kirstenbosch staff and other conservation scientists from all over the country"*.

2023 has been a significant year for our SANBI partners as they started work on South Africa's first wild plant seed bank. This is a huge step forward for seed conservation in South Africa and builds on the SANBI-Kew collaboration over the past 23 years, and funding from the Garfield Weston Foundation has played a significant role in getting to this point.

Mexico

Tree species of Mexico are undoubtedly one of the most important natural resources existing in the country. However, despite their widely documented importance, for the conservation of trees to be successful there are a considerable number of challenges to overcome. Large scale mega development projects and open pit mining present serious threats to the country's biodiversity. Kew's partners in Mexico are FESI-UNAM (in Mexico City) and the NGO Pronatura Veracruz. The aim of the project was to diversify plant conservation and propagation to support reforestation activities using seeds of native tree species. These species are important for the livelihoods of local communities and a further aim was to raise awareness of the ecosystem services they provide.

Summary of Progress

Fieldwork was carried out monthly in Veracruz state with FESI-UNAM providing training to collecting teams on collecting, processing and conservation. Accessions of orthodox species were conserved ex situ in the FESI-UNAM

seed bank and propagated, while desiccation-sensitive species were brought to nurseries for propagation and subsequent in situ conservation. Over the course of the programme, 580 seed collections of 232 species were made. Of these, 244 collections of 152 species were conserved at the FESI seed bank. 150 collections were used for research, 258 for propagation, and 106 for reforestation. 52 species were analysed for desiccation tolerance - 37 species were found to be desiccation tolerant, while 15 species were desiccation sensitive.

Eleven species were tested for germination requirements. A thorough literature review was performed prior to the laboratory activities, and appropriate treatments and temperature conditions were applied for each species. Results have been compiled and a scientific article will be submitted for publication in the first half of 2024.

Since 2020 the team has propagated 75,505 trees, 45,430 of which (93 species) were donated to local communities - 167 beneficiaries belonging to 36 municipalities - or used in reforestation trials. The remaining 30,075 trees are being currently maintained at the BMM Nursery (pictured below) and will be donated in 2024 when ready for donation. This work will continue under the next phase of the GTSB, with monitoring and germination testing of the five species selected and analysed for the 'forest germplasm units'.

The project in Mexico was involved in experimental reforestation trials using five species of community interest, and the plan is for best practise identified in these trials to then be applied to restore and/or reinforce original natural populations. As a result of these trials, the team have produced technical information sheets for 22 taxa, the printed versions of which will be distributed to recipients of tree donations from the nurseries.



Research Project Progress

Project: Improving the PReservation of difficult-to-store tree seeds - IMPRETS

IMPRETS aimed to increase understanding of tree seed form and function and the application of low temperature science to the preservation of tree seeds. The aim was to achieve a greater understanding of the principles underlying tree seed stress tolerance, survival, and germination as affected by the seed's structural biology.

Significant progress has been made on the part of this project which looks at the physical properties of tree seed coats. The entire selected set of 747 seed collections has now been assessed for seed covering structure hardness, alongside the collection of data regarding colour and seed morphology measurements, phylogeny, climate, plant lifeform, seed dormancy type and seed dispersal type. This has allowed the team to start analysing their data with the aim to understand some of the mechanisms underlying global variation in seed covering structure hardness of woody species. In addition, they collected data on species distribution range, germination speed and longevity during ex-situ storage. They will publish their work in an open access journal in 2024.

Work on the micro-morphology of cryo tolerance in temperate and tropical recalcitrant seed axes progressed well this year, and a report will be published in a peer-reviewed manuscript in 2024, once the final replicate images have been analysed.

Capacity building and training

In September 2023, the MSB's flagship Seed Conservation Techniques course took place online, with 21 participants chosen from more than 70 applicants. In October we held the first 'plant cryopreservation – theory and practice' course, at the MSB with 9 participants. This course was aimed at providing trainees with the knowledge and understanding they need to consider and apply different cryopreservation approaches for the ex-situ conservation of plants in their countries.

Over the course of three years, we have successfully delivered SCT training to 64 participants. We adapted our training programme during the Covid pandemic and delivered our training online. While online training will remain a strong option to support international partners at a low cost, we have returned to delivering significant elements of our training in person.



The SCT course in Madagascar

During 2023, a technical attachment at the MSB focused on exceptional species, and hosted participants from four GTSB partner countries, among others. In May, visitors from our GTSB teams in Mexico and Madagascar were able to join the Kew Diploma horticulture course. The students spent a week at the MSB looking at seed physiology, morphology and germination, along with a collection exercise in the Wakehurst landscape.

We hosted various online training modules including a workshop on 'collection and conservation techniques for medicinal and aromatic plants', jointly organised by our Pakistani GTSB partners and Kew for 43 participants, and a two-day training course on mapping hosted by a senior spatial analyst based at Kew, for participants from GTSB partners in Bhutan and Pakistan.

Phase 3 of the Weston Global Tree Seed Bank programme has greatly improved in country capacity through training and the provision of equipment. Overall, this project has trained over 300 participants who can contribute to the conservation of trees and nature across the world.