Samara

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Putting seeds to good use

Kyrgyzstan explores the pharmacological potential of its native flora

Landscape of Kyrgyzstan

Photo: RBG Kew

Samara

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Kyrgyzstan, despite its rather limited territory, has one of the richest floras in Central Asia, with around 4,000 species described to date, at least 10% of which are endemic or sub-endemic (i.e. grow only in Kyrgyzstan or slightly beyond its borders). The floristic diversity is partly due to Kyrgyzstan's geographic location in the heart of the mountain systems of Tian Shan and Pamir Alay, where the vegetation ranges from semi-desert to tall herb meadows and from fruit and nut forests to alpine pastures.

In 2005, work began on the *ex situ* conservation of Kyrgyzstan's plant genetic resources, led by the Institute of Biotechnology of the National Academy of Sciences of the Kyrgyz Republic (IB NAS), and supported by the MSB and the International Science and Technology Center (ISTC). The aim was to store plant genetic material in a national seed bank and in collections of *in vitro* tissue.

Preliminary phytochemical studies on the native flora identified over 180 species containing high levels of pharmacologically valuable compounds, and the in vitro collection focused on creating callus and root cultures of these for further study. One exciting result was the discovery that the endemic species, *Scutellaria andrachnoides* (skullcap) has a high content of wogonin, a promising anti-cancer agent, and two European Patent Society patents have now been

Royal Botanic Gardens Kew

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Staff of IB conducting field work.

obtained for the callus culture (EA No. 019010) and transformed roots culture (EA No. 020503). This development will enable easier production of plant tissues for the purposes of further research and it may lead to commercially viable *in vitro* synthesis of medicinal raw materials, which will protect the wild plant populations from illegal over-exploitation.

Seed banking in Kyrgyzstan has been progressing steadily over the last 13 years and currently around 30% of Kyrgyzstan's wild plant species have been collected and stored in the seed bank. The collection includes many rare, endemic and medicinal species. After a lull of a couple of years due to lack of funding, the IB has now launched a new four-year seed conservation project, which aims to bank a further 200 species, focusing on securing collections of new species from the genera *Astragalus, Scutellaria* and *Hedysarum*, all of which have shown promising levels of medical secondary metabolites.

Another objective of this project is to provide seeds of striking and beautiful plant species to contribute to the new Great Silk Road landscape, to be created near the Millennium Seed Bank at Wakehurst Place (see related article by Ed Ikin in this issue). We are excited to know that an area of Wakehurst will be allocated to showcase the wild plant diversity of Kyrgyzstan and publicise the plant conservation and research being done here. IB staff and collectors will continue to stock the seed bank with new species of native plants and duplicate seeds to the MSB under the signed memorandum between Kew and IB NAS Kyrgyz Republic.

In 2018, the Institute of Plant Biotechnology (IB) of the National Academy of Sciences of the Kyrgyz Republic, announced a move into a new direction for plant conservation and research, namely the creation of a DNA bank for the wild medicinal plants of Kyrgyzstan. The new DNA bank will help us to identify plant material and assess its conservation status. Going forward, it will also allow us to build our capacity to carry out comparative genetic analyses of our unique flora.

In October of the same year, staff from the IB collected species from *Astragalus* (11 species), *Scutellaria* (2 species) and *Hedysarum* (1 species). The material collected will be named by Dr Georgy Laskov at the Institute of Botany NAS KR. After collection, the quality and quantity of the isolated DNA from the samples are checked on a Nanodrop 2000 spectrophotometer and by using agarose gel electrophoresis. The samples are stored in an ultra-deep freezer (-80°C) for further analysis. The collected plant tissues will be the first collection stored in the DNA bank specifically for medicinal plants.

The Royal Botanic Gardens, Kew continues to provide great technical assistance with the creation of our seed and DNA banks. One of the capacity building activities involved employees from the IB, Dr Tatyana Chernysheva and Dr Sergey Hegay, travelling to the Millennium Seed Bank to participate in a Technical Training Course on Seed Processing in April 2018. Meetings were also held with staff based at Kew's Jodrell Laboratory to discuss collaborative work on taxonomy, phylogeny, and the technicalities of establishing a DNA and plant tissue bank. We hope that through this collaboration, we will be able to continue and expand our research into medicinal plants, maybe leading one day to a significant breakthrough in the search for drugs to combat cancer.

Joint seed collecting field work with RBG Kew and IB staff.

Collecting in the mountains of Kyrgyzstan.

A message from Jonas Mueller

Senior Research Leader, Seed Conservation, RBG Kew

Dear MSB partners, colleagues and friends. This is the last foreword I will write for Samara. After 14 years at Kew, and four years in my current position, my shift has finished, and it is time for me to pass the baton to someone new. I have seen some major progress made in various aspects of our work during this time. The Millennium Seed Bank Partnership has grown considerably, with more partners than ever, feeling part of a truly global conservation initiative. Together, we have established, and populated with data, the MSB Data Warehouse as our global data sharing platform. We have launched a new interactive webpage and the MSB standards are tested and recognised as an international gold mark for best practice. My Kew team alone has trained more than 600 individual partners over the last three years, through courses held at Kew and overseas. All these changes make a significant difference to plant conservation and research. Certain thematic areas, the global themes as we call them, have become more visible and important over the last five years; medicinal plants, trees and Crop Wild Relatives, to name only three. There are exciting times ahead of you, the members of the Millennium Seed Bank Partnership – the current Global Strategy for Plant Conservation (GSPC) comes to an end in 2020, and

the planning for post-2020 offers an excellent opportunity to shape the future of plant conservation for the next decade. What would I say remains the basis of our global partnership? It is the partners who form it, the network united by the passion for plants and seeds and their conservation, and the friendships that form and develop as a result. This is something I am most proud of and I feel very privileged to have contributed to it. Although I am off to pastures new, I will continue to lead on individual projects, so please stay in touch.

A message from Sandrine Godefroid

Conservation Officer, Research Department, Meise Botanic Garden, Belgium

In Lesueur National Park, Australia.

Seed banking is one of the essential components of an integrated approach to the conservation of plant species. In the past, the main objective was to conserve endangered taxa, just in case, in a future that was believed distant, the species would become extinct in the wild. Today, we are witnessing a revolution in seed banking strategies towards a more diversified use of stored seeds. In a world where financial resources are becoming increasingly scarce, seed banks have been able to adapt, and demonstrate the usefulness of stored seeds, not only for conservation/restoration, but also for research and education. Seeds are currently being used to respond to some of the most serious environmental problems facing the world. Ancestral genotypes can be recovered from stored seed and raised in common garden experiments with descendant genotypes, allowing for instance, empirical evidence for adaptive responses of plant reproductive traits to recent climate change. Seed availability is also improved nowadays. The numerous seed exchange networks between scientific institutions enhance valorization of *ex situ* collections while reducing costs (particularly those related to seed collecting expeditions). This issue of Samara focuses on seed sharing and use in the broadest sense, highlighting some of the most exciting projects that are ongoing across the MSB Partnership. I hope that the articles included in this issue will be inspiring and will convince you to use and share your seeds further. Buried in those seeds could be some of the most essential information that might change humanity's future.

Reintroduction of endangered grassland species in Luxembourg

SIMONE SCHNEIDER[1,2] & THIERRY HELMINGER[2] ([1]Intercommunal Syndicate for Nature Conservation SICONA & [2]National Museum of Natural History)

In a combined effort to restore deteriorated habitats and strengthen remaining populations of threatened plants in Luxembourg, the nature conservation body SICONA and the National Museum of Natural History are collecting seeds of rare and threatened native plants in the wild.

In Luxembourg, many species-rich nutrient-poor grasslands still exist, but their biodiversity and structure are often degraded and sites continue to disappear completely. In particular, lowland hay meadows, such as Molinia (purple moor-grass meadows) and Calthion meadows have lost rare and common species due to high levels of fertilization. Also, many of the characteristic species of species-rich grasslands are endangered. More than 40% of the taxa listed as threatened on the Red List of the vascular plants of Luxembourg are grassland species (Colling, 2005). To protect these species and strengthen existing populations, we started a programme of reintroduction.

In practice, we collect seeds of rare and declining grassland species (for example *Serratula tinctoria*, *Scorzonera humilis*, *Salvia pratensis* and *Succisa pratensis*) in the wild. These are grown to young plants at a nursery until they are transferred to reintroduction sites. Sites are chosen to match the ecological conditions required by each species in their typical habitats and may or may not be sites with a historical occurrence of the species in question. Most reintroductions are carried out on public sector land, especially on grasslands owned by the local authority members of SICONA (acronym in French for intercommunal syndicate for the conservation of nature).

Photo: Simone Schneider

Reintroduction of wildflowers at a natural site, which is an important method for protecting endangered species.

Within the last five years, we have reintroduced more than 14,000 young plants of 20 grassland species in about 70 meadows. Individuals are usually planted in groups of 50, the number of groups per site depends on the size and species composition of the site. The position of every plant is recorded with a high-precision GPS in order to monitor survival rate in the first years and to find out when juveniles appear.

We recently finished evaluating our reintroduction efforts over the last few years and found that survival is mainly influenced by the following factors: weather conditions directly after planting (especially water supply), damage by wild animals (snails, deer, wild boar) and the initial health of the plants. Highest losses occurred within the first two years after planting. Survival rates vary between species and sites, with survival rates ranging from 15 to 99%. Therefore, it is necessary to start with a sufficient number of young plants.

We found that species reintroductions were an effective method for creating new populations of threatened species and for restoring various grassland types. These reintroductions are undertaken within the framework of two LIFE-Projects financed by the EU, the Government of Luxembourg and SICONA's member local authorities. The national nature conservation plan published by the ministry of sustainable development sets targets for the protection of plant species, which include *in situ* and *ex situ* conservation measures. Only part of the collected wildflower seed is used for reintroductions and *in situ* conservation. The remaining seeds are conserved in the seedbanks of both the National Museum of Natural History and SICONA for long-term preservation.

Photo: Simone Schneider

Group planting of 50 individuals of *Oenanthe peucedanifolia* three years after planting.

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RBG Kew develops land restoration model to support sub-Saharan Africa Great Green Wall

PAOLO CECI (African Projects Coordinator, RBG Kew), EMILY AMBROSE (Projects Support Officer, RBG Kew), SIDI SANOGO (Regional Project Coordinator, IER Mali), & TIZIANA ULIAN (Senior Research Leader - Diversity & Livelihoods, RBG Kew)

In sub-Saharan Africa's drylands, increasing pressure on fragile ecosystems has resulted in continued land degradation, leading to increased poverty and driving further land degradation. To address this complex challenge, the Great Green Wall for the Sahara and the Sahel Initiative (GGWSSI), was launched in 2007 by the African Union Assembly.

As part of this initiative, the Royal Botanic Gardens, Kew has been coordinating the Great Green Wall Cross-Border Pilot Project in Burkina Faso, Mali and Niger since 2013. The project aims to build a restoration model and generate environmental and socio-economic benefits. In particular, the project collects relevant data in order to inform regional restoration projects, targeting improved ecological functioning and provision of ecosystem services (Ceci et al., 2018).

Under a number of Access and Benefit-Sharing Agreements (ABSAs), this collaborative project has been implemented in partnership with national institutions and local communities in the cross-border zone between the three countries (Bankass in Mali, Djibo and Dori in Burkina Faso and Téra in Niger).

A participatory approach has been used to select useful plant species adapted to local conditions and that are important to the communities' livelihoods. In 120 beneficiary village communities, participatory diagnostic meetings have been conducted, leading to the selection of 193 plant species, most of which are mainly used for food, medicine, fodder, and fuel (Sacande & Berrahmouni, 2016). The most environmentally well-adapted and economically relevant species have been prioritised and authenticated, and seeds have been collected from the wild and used for *ex situ* conservation and propagation.

Project implementation in the three countries has contributed to long-term conservation of 84 useful woody and herbaceous species, which have been collected and stored to international standards both at RBG Kew's Millennium Seed Bank and in national seed banks. Collections have been assessed through seed testing, including viability, germination, dormancy and barriers to storage. The resulting scientific information has been disseminated at international workshops held in Africa and through scientific articles. Research on seed biology and ecology has been carried out at RBG Kew to support the conservation and propagation of species.

Community consultation in Mali.

Seeds stored in Mali.

In collaboration with local communities, seeds of 55 woody and herbaceous species have been planted to restore 2,235 ha of degraded land and create sustainable income-generating opportunities for up to 32,000 people. Over 1,000,000 seedlings of the selected species have been planted in around 200 experimental plots. Species survival and growth (height and diameter) rate are monitored twice a year. Over 100 village technicians have been trained and supervised in seed collection and seedling production in local nurseries near the demonstration parcels.

Village nursery in Niger.

Project implementation has demonstrated the relevance of the approach developed by RBG Kew to restore degraded land through the propagation of useful species in communities and *in situ* conservation. RBG Kew can play an important role in the context of the GGWSSI by carrying out science-based conservation activities, and providing partners with technical expertise in seed management and germination, seed biology, seed ecology, and plant propagation.

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FURTHER INFORMATION

For further information visit:
https://www.kew.org/science/projects/great-green-wall-cross-border-pilot-project-burkina-faso-mali-and-niger
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Achieving GSPC Target 8 in Azerbaijan

VALIDA ALIZADE (Director and Project Manager, Institute of Botany, Azerbaijan National Academy of Sciences) & AIDA IBRAHIMOVA (Seed Bank Manager, Institute of Botany, Azerbaijan National Academy of Sciences)

The native flora of Azerbaijan is extremely diverse with more than 4,500 species of vascular plants. Approximately 64% of the species growing in the whole Caucasus can be found here and it is also part of the Caucasian Biodiversity Hotspot due to its floral diversity and high endemism (200 national endemics and 950 Caucasus endemics). Additionally, the flora is rich in relict species belonging to the Tertiary period, whose representatives can be found across the country.

The laboratory of the Seed Bank of the Institute of Botany, ANAS.

According to Target 8 of the Global Strategy for Plant Conservation (GSPC) 75% of threatened plant species should be included in *ex situ* collections by 2020, preferably in the country of origin, with at least 20% available for recovery and restoration programmes. In 2012, a Memorandum of Understanding (MoU) was signed between the Millennium Seed Bank, Kew and the Institute of Botany, Azerbaijan National Academy of Sciences. Within the framework of the MoU, a series of different projects were developed that play a significant role in achieving Target 8 by 2020 in Azerbaijan.

Since 2013, the Institute of Botany has been carrying out two projects in collaboration with the MSB. A key goal is to maintain regional genetic variability of endangered plants by seed collecting and conserving natural populations. The "Saving the Flora of the Caucasus: Azerbaijan wild species collecting" project ran from 2013 to 2018. As part of the project, the seeds of 239 plant species were collected. Out of these, 10 are national endemics, 18 Caucasus endemics, 28 are threatened and six are relict species. A second project, the "Global Tree Seed Bank Project", in conjunction with the Institute of Botany and the Central Botanical Garden, Azerbaijan National Academy of Sciences (ANAS). This particular project is focused on collecting and seed-banking 66 of the country's rarest, most threatened and useful tree species. Seed and herbarium collections, as well as data were successfully saved in the seed bank of the Institute of Botany and duplicated at the MSB.

Thanks to the support of these projects, the Seed Bank of the Institute of Botany (SBIB) was established in 2017. The SBIB is designed for short- and long-term storage of seed collections. It will also contribute to future investigations relating to the protection and sustainable development of plant biodiversity in Azerbaijan.

Collected seeds under these projects have been used for germination tests to determine the viability of seed collections to enable their long-term conservation and research. Seeds and bulbs of threatened plants have been incorporated into the living collections of the Central Botanic Gardens, ANAS. High quality seed collections are an effective tool for future conservation, particularly for genetic diversity, conservation, phyto-diversity restoration and sustainable use.

***Ophrys caucasica* (an endemic of the Caucasus) in the Central Botanic Garden, ANAS.**

Collecting seeds in the field

Young researchers experience the Austrian Alps through seeds

PATRICK SCHWAGER & CHRISTIAN BERG (Botanical Garden Graz)

Botanical gardens are places of teaching and learning, representing ecosystems from across the world, showcasing ecosystem-specific taxa, a variety of plant life strategies, and using seeds as an educational tool. One of the main tasks of botanical gardens is knowledge transfer, not only at the university level, but also for schools. The Styrian region of Austria includes a substantial part of the mountainous landscape making up the European Alps. As such, the Botanical Garden Graz has a strong responsibility to inform the public about these unique alpine habitats and the endemic vascular plant species that can be found within the eastern most part of the Alpine arc. As part of the Alpine Seed Conservation & Research Network, the botanical garden has developed a programme to raise public awareness of alpine ecosystems and to provide an interactive environment for young pupils to learn more about current research issues. Participants have the opportunity to gain insights into the *ex situ* conservation work taking place and to be introduced to problems associated with a changing environment. The activities range from seed counting and weighing, to examining different types of seeds under a microscope, to measuring microclimate conditions in the Alpinum (a part of the Botanical Garden that houses alpine plants). These "young researchers" also have the opportunity to ask questions and to participate in topical discussions. In the future, young people will be able to experience mountain ecosystems first hand, as the garden extends its activities to include an outdoor expedition programme for schools.

Young researchers in the Alpinum of Graz Botanical Garden.

Seed banking as a last resort for endangered plant populations

CATHERINE LAMBELET-HAUETER (Curator, Conservatoire et Jardin botaniques de la Ville de Genève [CJB])

For many years, the Conservatoire et Jardin botaniques (CJB) have worked in collaboration with the Nature Conservancy Agency (NCA) in Geneva for the conservation of endangered species (see SAMARA 31, p.6). The creation of a seed bank in the botanic garden has proved in many cases to be a crucial tool for the maintenance of highly endangered populations. The seed bank can effectively save seeds for years that can then be reused in case of emergency. This fact can be illustrated by a real case study.

The creation of a seed bank in the botanic garden has proved in many cases to be a crucial tool for the maintenance of highly endangered populations

Following land reclamation and changes in water regime, the last population of about 200 *Thalictrum flavum* in Geneva, discovered in 1990, had disappeared in 2006, despite *in situ* measures. Thanks to seeds collected in 2003, multiplication could be initiated by the gardeners at the CJB. In 2013, a new site was completely restored in nature to recreate a wetland and deemed fit to receive *Thalictrum flavum* plots. 350 individuals were planted by the gardeners of CJB in 2013 and 2014. After a difficult start, the management of the site was adapted by the NCA. Monitoring shows that the population has increased since 2015 and plants were starting to flower and set seed in 2016. In 2018, at least 53 plants were counted and 18 of them flowered and produced seeds.

Such examples have gradually encouraged collaboration with other institutions. Several Swiss cantons, which have done *in situ* conservation activities of certain species for many years are now adding *ex situ* activities in their programmes. For example, they are now collecting seeds to store in the CJB seed bank. These exchanges will allow for restoration of populations if initial measures taken in the field are not successful. Seed lots have already been redistributed to allow for the reintroduction of extinct or very small populations.

***Thalictrum flavum* flowering again in Geneva.**

Assessing the magnitude and implications of seed germination changes during *ex situ* cultivation

ANDREAS ENSSLIN (Scientist, Botanical Garden of the University of Bern, Switzerland) & SANDRINE GODEFROID (Conservation Officer, Meise Botanic Garden, Belgium)

The conservation of plants *ex situ*, i.e. in living collections or as seeds in seed banks, has become a central pillar in current global conservation efforts. The Global Strategy for Plant Conservation (GSPC) has set the ambitious target of safeguarding 75% of all endangered plants *ex situ*. This has resulted in a major boom of the *ex situ* conservation sector worldwide, and botanic gardens as major *ex situ* facilities, have strongly increased their investment in wild plant collections. There are currently more than 2,300 horticultural institutions such as botanic gardens, and over 350 professional seed banks worldwide storing and cultivating around 30% of known wild plant species (Donnell & Sharrock 2017; Mounce, Smith & Brockington 2017). While these numbers are impressive, there is not much knowledge about the quality of these collections, neither is there about how cultivation and seed storage can alter plant traits, and how these changes could affect the reintroduction success of an *ex situ* conserved species.

In a postdoc project at the Meise Botanic Garden (Meise BG), we sought to understand how seed germination traits, for example seed dormancy, can change during *ex situ* cultivation and storage, as well as how this could affect reintroduction outcomes. In a first step, we analysed a database of germination tests of more than 72 species, which have been cultivated in the Meise BG and stored for different durations at short-term storage conditions (15°C, 15% humidity) in the seed bank. We compared them with the same set of species, which were wild-collected and stored (but not cultivated) to examine possible differences in germination traits due to cultivation. We also investigated whether germination traits changed over different storage durations (1-25 years).

We found that short-lived species cultivated in the Meise BG germinated better and had substantially lower seed dormancy than the same species that were not cultivated (Figure 1b). We also found that the viability of seeds stored in short-term conditions (15°C, 15% RH) substantially decreased over time for all seeds and affected seed dormancy. After 10 years, the difference in dormancy, due to the generally low seed survival, was not observable anymore (Figure 1a). These results demonstrate that cultivation of wild, short-lived plants in a botanic garden, is likely to result in a loss of seed

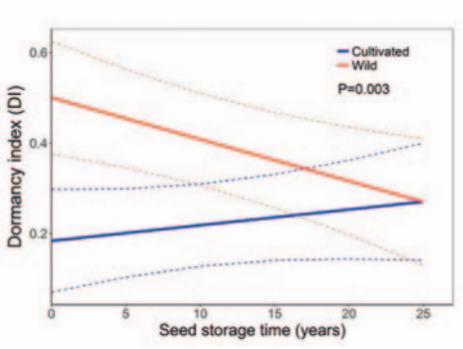

Figure 1a. Influence of seed storage time (at 15°C, 15% RH) on seed dormancy of 72 garden-cultivated (blue line) and wild-collected (red line) plant species.

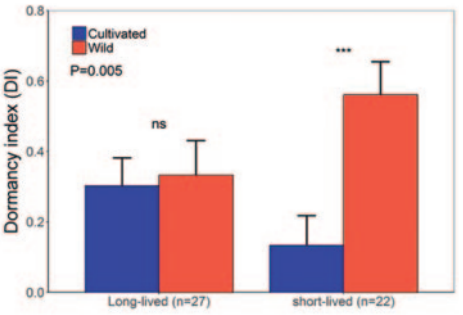

Figure 1b. Differences in seed dormancy between garden-cultivated (blue) and wild (red) plant species separated by their life span (long-lived vs. short-lived) (n = number of species in each group; ***= p<0.001). For details see Ensslin et al. 2018.

Figure 2: Sandrine Godefroid and Miel Wagemans transplanting 540 young individuals of *Digitalis lutea* from three different origins (garden-cultivated, wild-collected and seed bank) at a site close to the original wild collection area near Couvin in southern Belgium.

dormancy. To maintain natural seed dormancy patterns, it is therefore crucial to restrict regeneration of accessions with a conservation purpose to a minimum. The strong impact of seed aging on seed dormancy suggests that seeds from cultivated plants, but also seeds kept for several years under short-term storage conditions, should not be used for seed ecology studies. More information can be found in Ensslin et al (2018).

In the second part of our project, we wanted to know whether the observed changes in seed dormancy could have negative implications on the success of plant reintroductions. As seed dormancy is considered a bet hedging strategy employed by plants buffering high mortality during unfavourable periods, the lack of dormancy in cultivated seeds could thereby put the survival of the whole population at risk, for example when seeds germinate too early in spring (or even autumn) and are subsequently subjected to frost. Moreover, cultivation might have changed other traits in plants, such as plant architecture and reproduction,

Figure 3: Sandrine Godefroid and Andreas Ensslin measuring plant performance and reproduction in the same site than in Figure 2 in July 2018, 2 years after the initial reintroduction.

Figure 4: a) Andreas Ensslin sowing 100 *Digitalis lutea* seeds into buried iron rings in October 2016 in order to investigate seed germination patterns of garden-cultivated vs wild-collected seeds under natural conditions in a reintroduction site close the original wild collection area near Couvin in southern Belgium.

Figure 4: b) Germination patterns of *D. lutea* seeds after winter in April 2017.

again, potentially affecting reintroduction outcomes (Ensslin & Godefroid 2018). To investigate this, we focused on one particular species: the yellow foxglove (*Digitalis lutea* L.). In this species, we had observed a particularly substantial loss of seed dormancy in our germination tests, which happened during 30 years of cultivation in Meise BG. Here, seeds from the cultivation beds germinated with over 90% without cold stratification, while seeds from the original wild population collected in 1986 for the initial *ex situ* cultivation (and kept frozen at -20°C since then), as well as seeds recollected from the original wild population in 2015 had below 10% germination rates (A. Ensslin, unpublished data). This suggested that a strong selection against dormancy has occurred in the garden collection. We wanted to know whether this dormancy loss could also affect the survival and performance of the plants when re-introduced into their native habitat. To investigate this, we conducted a seed sowing and experimental transplantation experiment with all mentioned seed origins (garden-cultivated, frozen in the seed bank, wild-recollected). In October 2016, we sowed seeds into buried metal rings and transplanted 540 young plants into three sites in the surroundings of the original wild population (Figures 2 and 4a). In spring 2017, we recorded the germinated seedling in the sowing experiment (Figure 4b) and monitored the survival and performance of the plants in summer 2017 and 2018 (Figure 3). Preliminary analyses show a slightly higher germination of garden-cultivated seeds compared to wild-collected seeds in the field, while plant performance and seed production after 2 years seem higher in wild-collected plants (A. Ensslin, unpublished data). We will continue to monitor the transplantations in the coming years to investigate long-term dynamics and differences between *ex situ* reared and wild plants.

As *ex situ* conservation in botanic gardens and seed banks is becoming more acknowledged and internationally supported, it is crucial to assess possible problems and threats to improve current protocols and increase success rates of reintroductions. In our project, we showed that the current methodology in plant propagation in botanic gardens selects for early germination and thus, artificially reduces dormancy in *ex situ*-reared plants. Although this leads to higher seed germination rates, our preliminary results show reduced plant performance and reproduction when reintroduced into the wild. We would like to stress that this problem does not solely concern botanic gardens, but to a lesser degree also seed banks when seeds have to be regenerated due to low viability. To provide best-suited plant material for reintroduction, the implementation of protocols to avoid selection on life-history traits are essential. This will be the task for every manager dealing with *ex situ* conservation of wild plants.

The project was funded by the Swiss National Science Foundation (REV: P2BEP3_165405).

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A model of reforestation, food security and long-term carbon sequestration in Haiti

AVIRAM ROZIN (International Director, Sadhana Forest)

Since the earthquake in Haiti in 2010, there is growing awareness around the severe deforestation of the country. A few months after the earthquake, Sadhana Forest started its reforestation work in Anse-à-Pitres, southeastern Haiti. People there suffer from severe malnutrition so growing food could be a very strong incentive to plant and grow trees. A combination of fruits, nuts and edible leaves could dramatically improve the local nutritional status. Sadhana Forest's approach is to provide training in tree planting and care, harvesting produce, processing, cooking, and creating a healthy balanced diet. The trees are planted around homes to ensure they are watered and protected from animal grazing and cutting for charcoal production. Over the years we have refined our set of criteria for the choice of species. The trees to be planted should be indigenous, drought resistant, have a high wind resistance, since the area is frequented by hurricanes, produce food and preferably be oxalogenic, leading to a potential active oxalate carbonate pathway (OCP). Oxalogenic plants produce oxalic acid and transform it into calcium oxalate crystals within specialised cells called crystal idioblasts, ultimately utilising organic carbon, formed from atmospheric CO2 during photosynthesis. Calcium oxalate is insoluble and collects in nearby soils as the tree discards organic matter both above and below ground. This pool of calcium oxalate is then broken down by oxalotrophic bacteria present in the soil to form limestone (CaCO3), successfully sequestering CO2 within the geologic reservoir in the soil. Depending on climatic conditions, this carbon has a longer residence time within the soil compared to organically sequestered carbon. Thus, this long-term carbon sequestration is of particular importance given the ever-increasing emission of CO2 into the Earth's atmosphere.

***Genipa americana* seedling growing in the Sadhana Forest Haiti tree nursery.**

Our efforts to identify the appropriate species for reforestation led us to connect with the Millennium Seed Bank, RBG Kew and the seed bank of the Jardín Botánico Nacional Dr. Rafael M. Moscoso (JBN) in the Dominican Republic. The JBN did tremendous seed collecting work in Hispaniola funded by the Garfield Weston Global Tree Seed Bank Project among others. They have supplied us with a few interesting species that satisfied our basic criteria and two of them can potentially have an active OCP, including:

Sadhana Forest Haiti tree nursery.

Sadhana Forest Haiti team planting a tree.

Genipa americana L. - Cultivated for its edible fruit made into drinks, jams, and ice creams. The presence of oxalates has been confirmed in *Genipa americana* (Vasconcelos, et al., 2017) serving as strong evidence that the plant could have an active OCP in the right conditions.

Diospyros nigra (J.F.Gmel.) - A naturalised species in Haiti. Sweet, pudding-like fruits. It is safe to assume that it develops oxalate within its tissues, since calcium oxalate production has already been confirmed within the Diospyros family (Kumar, et al., 2011).

Hymenaea courbaril L. - Its hard pods have an edible pulp around the seeds. The sap is utilized in perfumes and varnishes.

The ongoing collaboration between RBG Kew and JBN is critical to the success of our land restoration model in Haiti. For further information please contact Aviram Rozin *(aviram@sadhanaforest.org)*.

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Benefits of conserving and using seeds of native tree species in Hispaniola

ELENA CASTILLO-LORENZO (Latin America Projects Coordinator, RBG, Kew), TIZIANA ULIAN (Senior Research Leader - Diversity & Livelihoods, RBG, Kew) & RICARDO GARCÍA (Director of Jardín Botánico Nacional, Dominican Republic)

Shared between Haiti and the Dominican Republic, Hispaniola island is the second largest Caribbean island after Cuba and has the highest concentration of endemic species (>2,000) within the Caribbean biodiversity hotspot. The diverse topography of the island (up to 3,175 m asl) results in different microclimates, ranging from hyper humid cloud forests to dry forest and flooded grasslands. Deforestation is currently the main problem on the island, with Haiti having lost nearly 97% of its forest cover, and the Dominican Republic at least 60% of its original forest.

Since 2015, RBG Kew has been collaborating with the Jardín Botánico Nacional Dr Rafael Ma. Moscoso (JBN) in the Dominican Republic, as part of the Global Tree Seed Bank project funded by the Garfield-Weston Foundation. The project 'Saving threatened forests of Hispaniola' aims to protect the forest diversity of the island by conserving threatened, endemic and useful trees through seed banking, seed biology research and plant propagation.

To date, the project has helped to store seeds of 172 desiccation tolerant tree species at the JBN seed bank and 96 of these have been duplicated at the MSB. In addition, 22 species have been found to be desiccation sensitive (recalcitrant) by applying a modified version of the 100-seed test protocol (Mattana et al., *in prep*.).

The results of this research carried out have guided the management and use of seed collections. To date, more than 175 tree species have been propagated, of which 43 have been planted *ex situ* and 39 reintroduced into degraded areas. Nearly 72 species have been donated to other organisations, for example, a collection of around 5,000 seeds of *Simarouba berteroana*, an endemic tree from Hispaniola, was donated to the Ministry of Environment and Natural Resources for reforestation activities and 40 trees were planted in Pedro Santa region along the Haiti border. Additionally, the JBN contributed to the greening of Santo Domingo by planting 150 native tree species in urban parks and gardens. Finally, the project has helped to increase public awareness of the use of native trees by planting several species as part of a new trail at JBN, designed to exhibit and teach the lifestyle of the Tainos (a pre-Columbian Caribbean civilization) and the plant species involved in their traditions.

The project collaborators of Jardín Botánico Nacional (JBN) visiting Kew with Garfield-Weston Latin America staff.

Staff members of Jardín Botánico Nacional Dr Rafael Ma. Moscoso (JBN) cleaning tree seeds.

Brígido Peguero, botanist at JBN and collaborator of the Garfield Weston project, showing part of the Taino's trail.

Creating living connections to science

ED IKIN (Head of Wakehurst Landscape and Horticulture, RBG Kew)

Garden-makers, from Gerald Loder in the 1920s to recent curators, always looked out to wild temperate regions for new plants, driven by a sense of discovery. As we plan Wakehurst's future landscapes, we find ourselves asking, where should our planting inspiration come from?

The Millennium Seed Bank gives Wakehurst an extraordinary opportunity for landscape partnerships. This potent combination of conservation and horticulture has the ability to connect seed bank collections to Wakehurst's visitors through the simple, tangible beauty of plants. Where possible, our new landscapes have Kew's conservation partnerships at their core.

A beautiful planting composed of IUCN 'threatened' taxa has the power to stir emotion and provoke new perspectives on plant conservation. That a plant might be thriving in our collection and critically endangered in the wild could challenge visitors' perceptions, pose questions about global threats and align with wider environmental causes. By practising a wilder style of design and drawing upon wild plant community dynamics, Wakehurst can offer a distinctive reason to visit over local, more horticulturally formal gardens.

The partnership between Wakehurst and Kew Science is starting to bear fruit, manifesting in three new landscapes:

The North American Landscape will evoke the dynamics of a North American non-woody plant community, translated into a large-scale immersive design over 22,000m2. Horsebridge Wood is Wakehurst's dramatic take on a North American woodland. The new complementary design draws upon our 'wild plants from wild places' philosophy to bring the beauty of the prairie, chaparral and sub-alpine meadow to our visitors. Beauty will be underpinned by a compelling story: of habitat loss, useful plants and ecological forces. Composed with a high proportion of wild collected seeds, facilitated by Kew's North American partnerships, these will be plants with a story to tell.

Collecting seed of *Helianthemum songaricum* along one of the northern Silk Roads, in the Boom Gorge, Kyrgyzstan.

The Kyrgyzstan flora is highly diverse – many endemic species are hidden within its extensive mountain ranges and on the lower slopes, the hay meadows are one of the great global wild flower spectacles. Kew's conservation partnership with Kyrgyzstan aims to bank the country's flora, with the MoU permitting seed to be used for education and display. After experiencing Kyrgyzstan's flora first hand on a field trip to Lake Issyk-kul in 2017, Wakehurst horticulturists are trialling hay meadow combinations using banked seed, with the aim of creating a colourful Silk Road Steppe representing the Eurasian grasslands. We're exploring different forb/ grass ratios and soil amelioration techniques, such as growing in sand and grit, to simulate wild ecological stresses.

The Caucasus fruit and nut project, funded by the Darwin Initiative, a UK Government scheme, will conserve Georgia and Armenia's extraordinary reserves of wild crop ancestors, including *Malus*, *Pyrus*, *Corylus* and *Prunus*. Wakehurst horticulturists will support the project through capacity building activities such as the establishment of horticultural village plots to reduce exploitative wild harvesting. As the relationship develops, Wakehurst will seek crop wild relatives that score highly for beauty, story and conservation significance. Together with in-country partners, seeds and cuttings of these taxa will form a new Ancestral Orchard at Wakehurst, connecting our visitors to the origins of modern crops and the beginning of cultivation and food preservation as catalysts for the increasing success of our species.

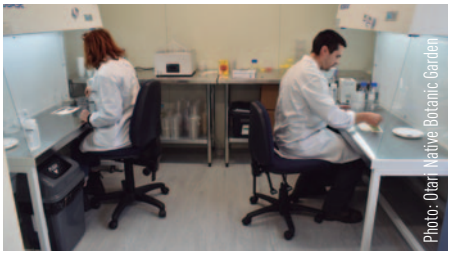
New landscapes, telling the story of Kew Science's work through wild collected plants gives Wakehurst a unique position within British horticulture. As Kew's wild botanic garden, we can create new connections between people and plants, contribute to *ex situ* conservation targets and bring the work of the Millennium Seed Bank out from its vaults and into the garden.

Ex situ conservation of Myrtaceae, a response to Myrtle Rust in the Pacific Region

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

The discovery of Myrtle Rust (*Austropuccinia psidii*) in Aotearoa New Zealand in May 2017 resulted in all Myrtaceae species being listed as Threatened according to the National Threat Classification. Since *A. psidii* is a new pathogen in our ecosystems, the exact impact on species, ecological communities and landscapes is not known, although global studies reveal significant impacts. Formerly widespread species such as *Rhodamnia* and *Rhodomyrtus* in Australia are now facing extinction in the next five years due to tree mortality and reproduction failure following the establishment of Myrtle Rust. With limited control options for this wind-borne pathogen, one of the most important actions involves the creation of genetically diverse *ex situ* germplasm collections.

Although seed of some genera such as *Metrosideros, Leptospermum* and *Kunzea* can be effectively stored using conventional seed banking methods, other taxa including *Metrosideros bartlettii*, *Syzygium maire*, *Lophomyrtus* and *Neomyrtus* require more research due to low or no seed production and seed characteristics. At the new Lions Otari Plant Conservation Laboratory (est 2018), we are using collections of *S. maire* to study seed characteristics and cryopreservation of the species. In addition, we are focusing our research on hand pollination of *M. bartlettii* and establishing additional back up collections through tissue culture.



Staff using the Lions Otari Plant Conservation Laboratory to study seed characteristics.

Millennium Seed Bank seed distribution and use. The UK Programme as a case study

JANET TERRY (Seed Collections Manager, RBG Kew), TED CHAPMAN (UK Native Seed Hub Project Co-ordinator, RBG Kew), STEPHANIE MILES (UK Collections Co-ordinator) & CLARE TRIVEDI (UK Conservation Partnership Co-ordinator)

Did you know that the Millennium Seed Bank distributes over 1,000 samples of seed annually? It is vital that the collections are available for use by any non-commercial organisations with a genuine need for them. Many of the species held by the MSB are not available anywhere else, making these collections especially important and unique.

The online MSB seed list (*http://apps.kew.org/seedlist/index.html*) is available for anyone to look at, but in order to receive seeds customers must register and meet certain criteria. In addition, seed collections must also meet strict criteria in order to appear on the list. These include: having a sufficient number of seeds; having their taxonomy verified; and being covered by an agreement with the partner organisation who collected and donated the seeds that permits distribution.

Seeds ready for distribution.

Requested seeds are used by researchers, botanic gardens, educators, archaeologists and exhibitors. They may also be used for species re-introduction projects. Customers receive 50 seeds, together with germination instructions. If more seeds are required, recipients can grow the plants on and harvest more seeds as necessary.

The MSB's UK Programme is a great case study on seed collection use both for species and landscape level restoration. The programme is structured around three projects: the UK Flora project, which makes collections across the entire UK flora for long term conservation at the MSB; the UK National Tree Seed Project (UKNTSP), which is building genetically representative collections of native woody species; and the UK Native Seed Hub (UKNSH), which uses the seed collections and associated expertise to increase the quantity, quality and diversity of native plant material available to practitioners in the UK.

Between 2012 and 2017, 1,290 samples from the UK collections were dispatched. 930 (72%) were used for research purposes, 206 (16%) to produce plants for the living collections and 154 (12%) for environmental purposes including regeneration, reintroduction and habitat restoration projects. In the UK, the UKNSH has made larger quantities of seed available via the UKNSH Seed List and through a range of partnership, project and consultancy work. Between 2011 and 2018, the UKNSH provided plant materials and technical assistance to 57 projects, working with 31 partner or client organisations including the Wildlife Trusts, the National Trust, the South Downs National Park, Natural England, local authorities, ecological consultancy firms, Toyota Motor Manufacturing (UK) Limited and Toyota GB (PLC).

The breadth and increasing diversity of collections held in the MSB represent an exceptional resource for species recovery and reintroduction projects, particularly of rare, highly threatened and protected species. In some cases - *Ranunculus ophioglossifolius* Vill. and *Chenopodium urbicum* L., for example - collections have been used to augment dwindling wild populations or reintroduce otherwise extinct populations to their original growing site.

In at least one case, *Bromus interruptus* (Hack.) Druce, MSB collections have facilitated the reintroduction of an endemic species that has become extinct in the wild.

At the landscape level, the UKNSH enabled regeneration of the South Downs grassland using collection of seeds from 25 species of known native-origin. The project produced plug plants to enhance existing grassland, for direct sowing to restore grassland following scrub clearance, to reinstate grassland damaged by road construction in protected areas and to provide a bespoke mixture of larval and nectar food plants to create butterfly habitat. Such projects provide a valuable opportunity to link the MSB's *ex situ* seed collections and associated expertise to practical conservation at landscape scales.

NEWS

Major Seed Bank Opens in United Arab Emirates

DAVID APLIN (Senior Executive, Sharjah Botanic Garden)

In February, a major new seed bank was inaugurated in the United Arab Emirates by His Highness Sheikh Dr Sultan bin Muhammad Al Qasimi, Ruler of Sharjah emirate. The facility, located in the town of Al Dhaid is known as the Sharjah Seed Bank and Herbarium (SSBH).

SSBH was founded in 2009 with technical support from the Millennium Seed Bank of the Royal Botanic Gardens, Kew. The new 2,450 m2 building comprises nine laboratories for seed drying, cleaning, testing, DNA analysis and micro-propagation. There are extensive refrigeration and freezer rooms for long- and short-term seed storage, a herbarium, four meeting rooms, and a library and auditorium with seating for over 100 guests. The facility has state of the art equipment for seed testing and molecular work making this facility one of the most advanced of its kind in the region. The activities of SSBH focus on the indigenous flora from the region, whose botanists also record and monitor native plant distributions.

The inauguration of SSBH represents a major addition to Sharjah's long-standing effort to preserve plants and biodiversity in the region and protect endangered species using *in situ* and *ex situ* conservation techniques. It also demonstrates His Highness' personal interest in plants, who has a bachelor's degree in agriculture and at a young age gathered seeds and made his own seed collection from the Emirates.

Researcher, Hatem Shabana describing the process of making herbarium vouchers to His Highness Sheikh Dr Sultan bin Muhammad Al Qasimi, Ruler of Sharjah and delegates.

SSBH is joined by a more recent initiative to develop Sharjah Botanic Garden, a major new project in the region that will target research, education, conservation and display. Further information can be found at *www.botanicgarden.ae*

Enhancing rural Caucasian community livelihoods through fruit and nut conservation

AISYAH FARUK (Country Programme Officer [Caucasus], RBG Kew), CATIA CANTEIRO (Species Conservation Assessor, RBG Kew) & HELEN CHADBURN (Species Conservation Assessor, RBG Kew)

On the 1st of July this year we officially started the Darwin Initiative-funded project; *Enhancing rural Caucasian community livelihoods through fruit and nut conservation* (fruit & nut project for short!). This project is a three-year venture, involving our long-term partners in Georgia and Armenia (National Botanic Gardens of Georgia; Institute of Botany, Ilia University, Georgia; and Nature Heritage an NGO in Armenia).

One of the project's main activities is to engage with local communities and introduce them to plant conservation, as well as to teach ways of sustainably harvesting wild fruit and nut species. We aim to further alleviate wild harvesting pressures by utilising the seeds collected to promote the development of cultivation plots within community grounds. In addition, the project aims to train local partners in conducting IUCN Red List Assessments, so they are able to successfully assess those species thought to be at risk.

In early September, I travelled to Yerevan, Armenia, to meet with project partners. The intention was to brainstorm and finalise plans for the upcoming community engagement activities. It was a great exercise, as it allowed coordinators from the three organisations to work together to ensure the outcomes from the activities can be comparable between the two countries. I was closely followed by Catia and Helen from the Kew Plant Assessment Unit, who expertly conducted the IUCN Red List Training course for 14 participants from Georgia and Armenia. The participants ranged from students to experienced researchers. After all the hard work, a well-deserved celebration dinner was held, which included plenty of locally sourced fruits and nuts!

For more information visit our Kew Science Project Page: *https://www.kew.org/science/projects/enhancing-rural-caucasian-livelihoods-through-fruit-and-nut-conservation*

The "fruits" of our labour - brainstorming ideas for community engagement activities.

Catia, Helen and all 14 participants with their certificate of completion at the end of the training event.

Seed conservation standards reviews raise the bar for Australian partners

DAMIAN WRIGLEY (National Coordinator, Australian Seed Bank Partnership);
EVA MARTENS (Millennium Seed Bank Partnership Administrator, RBG, Kew)

In early 2018 a series of Millennium Seed Bank Partnership (MSBP) Seed Conservation Standards reviews were carried out across the MSBP network in Australia. The 20 MSBP Standards cover all aspects of seed banking: collecting, processing, storage and duplication, viability monitoring, data management, distribution and seedbank management. Through adherence to the Standards, the Australian partners are applying the highest level of technology and care to conserving Australia's unique flora.

The Standards review process helps to identify a seed bank's priority areas for development, which is a useful tool when resources and funding are limited. The process also neatly identifies 'quick-wins' – simple alterations to a seed bank's practices that can be made easily and with no extra cost, but which could have a significant impact on the quality of seed collections.

The members within the Australian Seed Bank Partnership (ASBP) have varying levels of experience and different resourcing profiles across the network. The Standards reviews are already enabling the ASBP to make comparisons between the different facilities and focus their capacity with a more strategic approach to seed conservation on a local, regional and continent-wide scale.

The completion of reviews of all the MSBP's Australian seed banks is important for the future of *ex situ* conservation of Australia's native flora.

"I recommend the approach to other MSBP partners who are looking to improve the way they approach seed banking. The baseline information gathered enables us to monitor the effectiveness of the conservation work that we do and identify priority areas for capacity development for seed conservation." – Damian Wrigley, National Coordinator of the ASBP.

Phyllodes, pods and seeds of *Acacia tolmerensis* in low sandstone outcrops near Tolmer Creek, Litchfield National Park NT.

FURTHER READING

The Millennium Seed Bank Partnership Seed Conservation Standards for 'MSB Partnership Collections'. (2018), RBG Kew. *http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/MSBP-Seed-Conservation-Standards.pdf*

Data Warehouse adds IUCN red list categories and criteria to seed collections

NAOMI CARVEY (Millennium Seed Bank Partnership Data Warehouse Project Officer, RBG Kew)

The Millennium Seed Bank Partnership Data Warehouse now includes IUCN red list categories for assessed species. IUCN categories and criteria are located in the Botanical Records table and can be shown in the Google maps interface. Within the map interface, simply switch from the default colour scheme to the IUCN value colour scheme – remember you will need to remove the map marker clustering first.

All species with a rating of Endangered (EN), Critically Endangered (CR) or Extinct in the Wild (EW) are now routinely fuzzy mapped to protect their exact location, whilst allowing the approximate collection vicinity to remain visible. If you would like more details on fuzzy mapping please contact the Data Warehouse administration team <*msbp.datawarehouse.access@kew.org*>.

Access to the MSBP Data Warehouse is open to all MSBP partners. If you would like to get access, first please register on the Data Warehouse website (*http://brahmsonline.kew.org/msbp/Account/Register*) and then email the Data Warehouse admin team (*msbp.datawarehouse.access@kew.org*) stating that you have registered and would like access.

Data Warehouse collections which are Vulnerable, Endangered, Critically Endangered and Extinct in the Wild

New MSB Agreements

Country/Territories	Counterpart Name	Start Date	Duration (Years)
Spain	The Universidad Politecnica de Cartagena *	July	4
Japan	The University of the Ryukyus*	August	5
Armenia	Nature Heritage NGO*	July	3
Australia	Council of Heads of Australian Botanic Gardens Inc.	November	5
Taiwan	National Museum of Natural Science*	August	5
Bahamas	Bahamas Ministry of the Environment and Housing, Forestry Unit*	June	2

*denotes new partner for the MSB

Key science publications

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Rivière, S., Breman, E., Kiehn, M., Carta, A. & Müller, J. (2018). How to meet the 2020 GSPC target 8 in Europe: priority-setting for seed banking of native threatened plants. Biodiversity and Conservation. 27. 1873-1890. Available online.

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Bursaries available for Kew's MSc in Plant and Fungal Taxonomy, Diversity and Conservation

If you would like the opportunity to study at the Royal Botanic Gardens, Kew, then why not consider applying to study on Kew's MSc course, which is run in conjunction with Queen Mary University of London?

The course focuses on global plant and fungal diversity, building up essential taxonomic skills and their application through taught modules including evolutionary biology, conservation and ecosystem science. Students also take part in a field trip to Kew's Madagascar Conservation Centre to develop skills in conducting botanical and mycological surveys. You will spend the majority of your time being taught by world-leading experts at Kew, along with access to Kew's scientific collections and archives. The MSc also includes a six-month research project, where students work alongside some of Kew's 300+ scientists – either at Kew Gardens or The Millennium Seed Bank, Wakehurst.

For 2019, there are a number of fully-funded bursaries available, covering both university fees and all travel and living costs. To discover more about the MSc and the bursaries available, visit www.kew.org/msc

MSB dashboard

Date	01/10/18
Total Collections	90,155
Total countries (including overseas territories)	189
Total Families	353
Total Genera	5,992
Total Species	39,777
# of Good Seeds	2,286,668,584
Collections Despatched	10,752

Next issue

Next issue: Issue 35 of Samara will report on community engagement. We would like to hear stories from MSB Partners on how your institution and/or projects engage with communities in your country/territory. Or if you are not involved in any specific community engagement activities, maybe you would like to showcase how volunteers from your local area have contributed to projects. If so, please contact our editorial team, we would love to hear from you.

TALES FROM THE FIELD

Fieldwork is an important part of the work that we all do. We'd love to hear about your fun, interesting and exciting field trips. Send your contributions to our editorial team!

Contact us

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.

The Millennium Seed Bank Partnership is managed by Royal Botanic Gardens, Kew.

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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.

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