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Botanic gardens and seed conservation: making progress towards GSPC Target 8

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Plants for the Planet

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Cover Photo: Kate, a Chicago Botanic Garden Conservation & Land Management intern, making a Seeds of Success collection of Nevada sumpweed (*Chorisiva nevadensis*) for the Bureau of Land Management's Carson City District Office in Nevada (BLM Carson City District Office, Seeds of Success)

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United Nations Decade on Biodiversity

EDITORIAL
BOTANIC GARDENS AND SEED BANKS

Seed ready to be banked (Germplasm Bank of Wild Species, China)

Seed banking is a vital component of plant conservation. Many botanic gardens around the world maintain effective seed banks for wild plant species, contributing to the long term and efficient storage of plant diversity. Seed banking is particularly important at a time of rapid global change both for threatened species and, increasingly, for more common species that may be essential in restoration programmes. As Professor David Bramwell wrote in BGjournal in 2007, "*if adapting to climate change is to be successful, current seed bank partnerships need to be developed into a worldwide network of seed banks with the objective of conserving the seeds of wild plants on a global scale.*"

In this issue of BGjournal, Kay Evelina Lewis-Jones notes that, "*collecting seeds seems to be more than just a pragmatic and efficient solution to an uncertain future. It builds on a long legacy between humans and plants. It is a promise*".

International environmental policies encourages seed banking. Target 8 of the Global Strategy for Plant Conservation (GSPC) calls for "*at least 75% of threatened plant species in* ex situ *collections, preferably in the country of origin, and at least 20% available for recovery and restoration programmes*". The Plant Conservation Report 2014: *A review of progress towards the Global Strategy for Plant Conservation 2011-2020* prepared by BGCI last year noted that at a global level, 29% of the species listed on the 2013 IUCN Red List are known to be in *ex situ* collections. This provides only a limited representation of globally threatened plants because progress in conservation assessment remains slow. Higher percentages of threatened plants are recorded in *ex situ* collections at regional and national levels. The report also notes the need for *ex situ* collections to be more genetically representative with greater emphasis given to seed conservation. The paper by Halász and colleagues in this issue notes how quickly progress can be made to meet GSPC Target 8 with appropriate resourcing and focussed national activity. Through the Pannon Seed Bank project over 60 percent of Hungarian endangered plants have been seed banked.

Collaboration is essential at a local, national and global level for seed banking to be most effective. The article by Evan Meyer in this issue explains how different organisations are gearing up to seed bank the entire Californian flora. The Hawai'I Island Native Seed Bank, described by Wagner and Ponthieux, is also a collaborative venture that links into a State-wide network again, conserving the plants of a globally important centre of plant diversity and endemism.

At a larger geographic scale, Jie Cai describes the impressive progress in seed banking in China. The Germplasm Bank of Wild Species based in Kunming aims to conserve 10,000 Chinese species by 2020. The centre is also working with 71 organisations throughout China that are conserving native local seed.

As Bardin and Buord point out "*frozen seed collection is not an achievement in itself, but an essential tool for conservation action, specifically* in situ *reintroduction or population reinforcement*". Increasingly the need to restore plant assemblages in degraded vegetation is one of the factors encouraging seed bank development. In Europe there is not yet sufficient seed to meet the demand for ecological restoration. Costantino Bonomi describes a new project which aims to promote the use of native seeds for grassland restoration and increase European production.

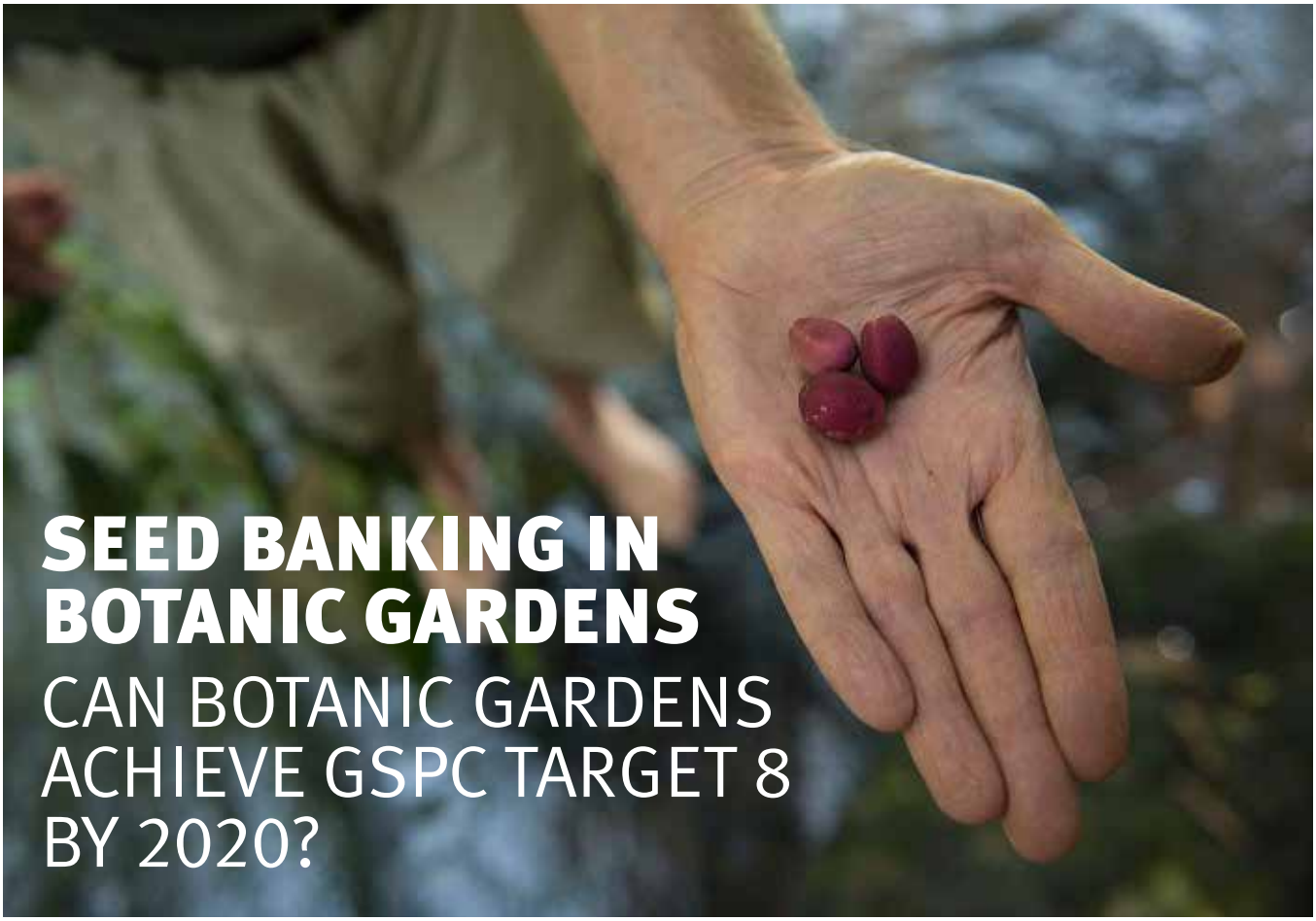
In this issue of BGjournal we present the results of a survey carried out by BGCI at the end of 2014 on seed banking activities in botanic gardens. It is clear that although there is a lot more work to do to meet GSPC Target 8, a good baseline is in place and many of the technological challenges in seed banking have been overcome. Making a strong case for the value of seed banking to ensure allocation of funds and building capacity around the world remains essential.

This will be my farewell editorial for BGCI as I step down from the role of Secretary General at the end of February 2015. It has been a huge privilege to work for BGCI for the past ten years and I would like to thank all involved in the wonderful global botanic garden network for their friendship and support.

With all good wishes for 2015.

Sara Oldfield
Secretary General, Botanic Gardens Conservation International

Authors: Katherine O'Donnell and Suzanne Sharrock



SEED BANKING IN BOTANIC GARDENS

CAN BOTANIC GARDENS ACHIEVE GSPC TARGET 8 BY 2020?

Above: Seed collecting (Barney Wilczak).
Right: Collecting seeds (Bureau of Land Management - Las Vegas, Seeds of Success)

Introduction

It has recently been reported that only 29% of plant species on the IUCN Red List of Threatened Species™ are in *ex situ* collections (Sharrock *et al*., 2014). Target 8 of the GSPC calls for '*at least 75 per cent of threatened plant species in* ex situ *collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes*' by 2020.

With less than 6% of the estimated 400,000 species of plants formally assessed at the global level using IUCN criteria, monitoring progress of *ex situ* conservation is difficult. However it is clear that more needs to be done if this GSPC target is to be realised.

Seed banking

Orthodox seeds can be collected from plants, dried and stored in cool conditions until they are required for research, restoration or reintroduction. Seed banking is increasingly being used as a method of *ex situ* conservation for a variety of reasons:

- It is the most cost effective method of *ex situ* conservation;
- A higher genetic diversity can be sampled when collecting than for living collections;
- Seeds take up less room than living plant collections;
- Seeds can survive for hundreds of years in conditions of low humidity and low temperature.

Botanic garden seed banks: the current situation

In order to identify the gaps in seed banking it is essential to determine the baseline situation. BGCI has therefore recently carried out a global review of the role of botanic gardens in seed conservation.

This review was based on information from BGCI's GardenSearch and PlantSearch databases along with data from the Millennium Seed Bank Partnership (MSBP) of RBG Kew, and the results from a recent BGCI survey on seed banking in botanic gardens.

The survey was sent to GardenSearch contributors in over 700 institutions. 271 individual institutions responded from 65 countries. The questions in the survey aimed to determine:

- Which institutions are involved in seed collecting and banking;
- What protocols are being used for collecting and banking;
- Seed storage facilities and conditions available in botanic gardens;
- Institutional reasons for seed conservation;
- The limitations preventing gardens becoming involved in or doing more seed conservation;
- Data management of accessions and use of PlantSearch to share data.

Seed survey results

Seed collecting

Nearly 80% of the institutions that responded to the survey collect seed as part of their work. The main reasons for collecting seed include conservation and back up/replacement of the living collections. There is a strong emphasis on collecting seed of threatened or endemic taxa within these gardens.

A number of gardens (74) that collect seed do not presently bank this seed. This is due to several factors, including lack of trained and available staff, lack of infrastructure, insufficient funding and lack of institutional priority. Of these institutions more than 80% would be interested in banking the seed they collect. This includes institutions in nine countries where there are currently no botanic gardens involved in seed banking.

Collecting cactus seeds (Student Conservation Association, Seeds of Success)

Seed banking: the global overview

It is recognised that many institutions in a wide range of countries collect and bank seed. However in many cases, seed banking focuses on agricultural crops and falls within the remit of agricultural institutes and agencies. The focus of our survey was to identify institutions involved in seed banking of wild plants, and particularly threatened species, which are generally not included in agricultural seed banks.

The results of the survey allowed us to identify over 50 institutions involved in such seed banking on which we previously had no data. In order to determine a global overview, this information was combined with that of MSBP project partners (Cable S. *et al*., 2014) and information from GardenSearch.

The analysis revealed that at least 421 institutions are involved in seed banking of wild plants in 97 countries (Fig.1). Botanic gardens are the main institutions involved in such seed banking, however

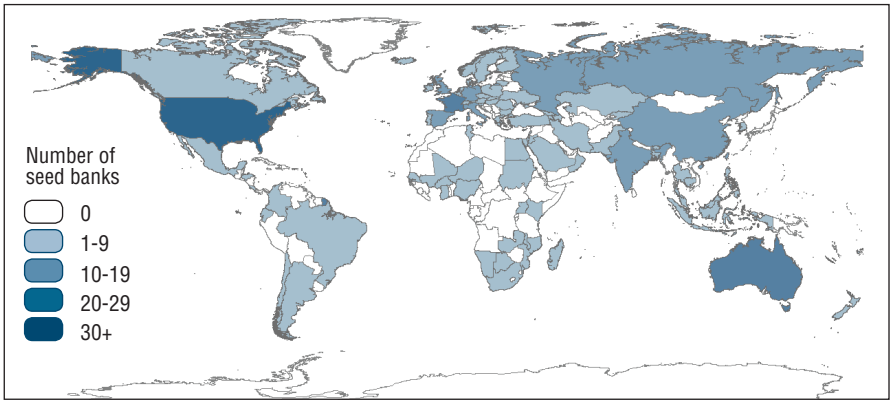


Figure 1. Number of seed banks per country.

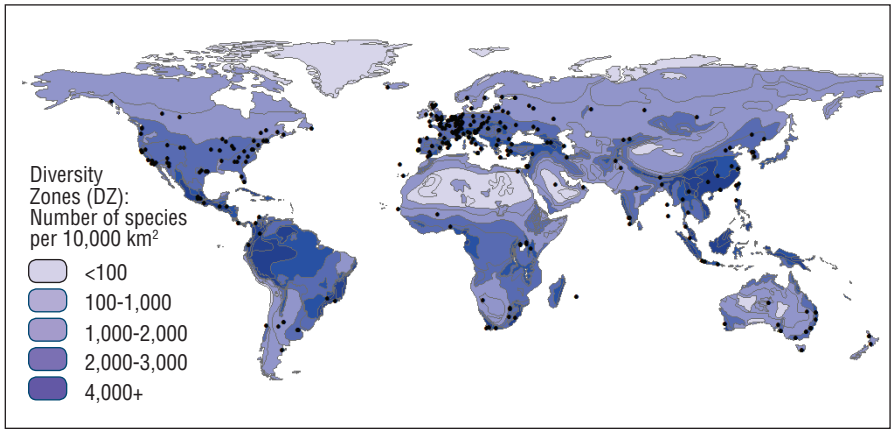


Figure 2. The location of seed banking institutes with relation to plant diversity

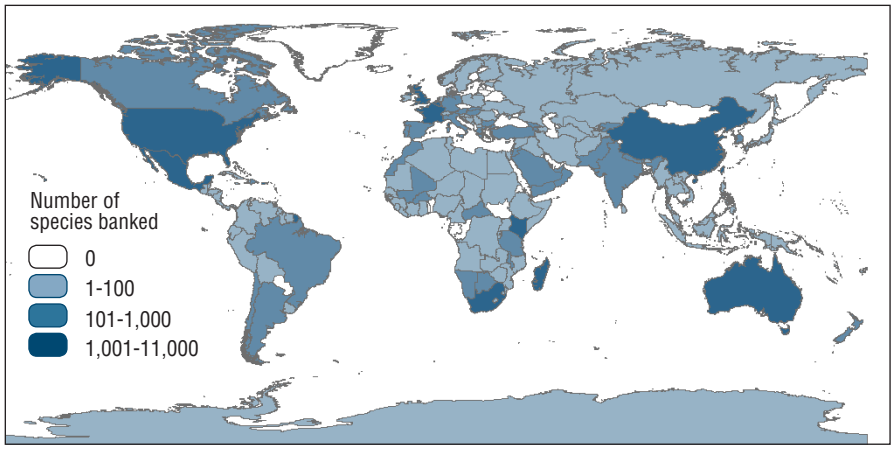


Figure 3. The number of wild taxa banked per country

a variety of other types of institution were also identified, including arboreta, universities, natural history museums, forestry and tree seed centres, science institutes and even zoos.

As expected, the number of seed banks per country is not even. Several countries including the United States, Australia, and France have more than 20 institutions involved in seed conservation. However, for the majority of countries, we have so far identified only 1 or 2 institutions involved in seed banking for wild plants.

"*Our seed banking work just beginning, there are lots of things needed to prepare and learn*". Binjie Ge, Shanghai Chenshan Botanical Garden, China

Information on countries where few or no wild plant seed banks exist was analysed against patterns of plant diversity to determine gaps in seed banking (Fig.2). Central Africa, South America and South East Asia were highlighted as the main regions with high plant diversity but limited seed banking activity.

The survey also revealed that the majority of institutions involved in seed conservation, bank seed at their own institutions. Those that don't have their own institutional facilities are either involved in the Millennium Seed Bank Partnership and store seed at the MSB seed bank in the UK or bank their seed at another institution in-country.

Number of species conserved

BGCI's PlantSearch database acts as an essential tool for monitoring progress towards Target 8 of the GSPC. Gardens are able to upload their living plant, seed and tissue collection data to this global database.

Of the survey respondents that collect and bank seed, the majority do not upload their seed accession data to PlantSearch. Those that do mostly upload their seed accession data under a different institutional profile to that of the 'parent' botanic garden. This is then listed as institution type 'Gene/Seedbank' and the accession data can be distinguished from that of living plant collections.

Using PlantSearch data, we are only able to identify 37,937 distinct taxa in seed banks around the world. The majority of these are from the MSBP which has approximately 34,000 taxa in its seed bank. However, recipients of the survey were asked how many wild collected species/taxa their seed banks held. Analysis of this data suggests that at least a further 17,000 taxa are being banked by botanic gardens around the world. For MSBP data the country of origin of the collections is known. For additional collections highlighted by the survey, it was assumed that the seed banking country was the country of origin. This data was analysed at the country level to show the number of banked taxa globally (Fig.3). There are several countries where we are not aware of any seed collections of wild plant species. A high number of species have been banked in the United Kingdom, United States, Australia, China, South Africa and France,

Seed banking standards

The protocols used for collecting and banking seed are important in order to ensure high quality seed of conservation value. When conserving seed it is essential to aim for high genetic diversity and maximum viability.

Collecting cactus seeds (Desert Botanical Garden - J. Johnson, Seeds of Success)

Seeds should be collected from a large number of individuals within a population in order to capture the most genetic diversity. In order for seed to have a high viability, efforts must be made at the time of collection to gather mature and viable seed.

There are a variety of protocols used by institutions involved in seed conservation including those developed by the MSBP, ENSCONET (European Native Seed Conservation Network) and the Seeds of Success. The majority of institutions however collect and bank seed using their own institutional protocols.

Drying seed increases its longevity and is essential for long term storage. For every 1% decrease in moisture content the life of a seed is doubled (Harrington, 1963). Based on the results of the survey, 65% of the institutions that collect and bank seeds have drying facilities which range from the use of desiccants such as silica gel to more costly incubator driers and drying rooms. 26% don't have any drying facilities and 9% did not respond. Nearly all of the institutions that do have drying facilities bank for the medium (1 to 5 years) or long-term (more than 5 years).

"*Long term storage is an issue, given the specifications needed for adequate humidity and temperature control.*" Nick Gershberg, The Arthur Ross Greenhouse at Barnard College / Columbia University.

Once dried, seed should be placed in hermetically sealed containers in order to keep moisture out. The most efficient containers are trilaminate foil which can be heat sealed and glass jars with air tight lids (Gold and Manger, 2014). Paper packets were found to be the most commonly used containers that seed collections were stored in.

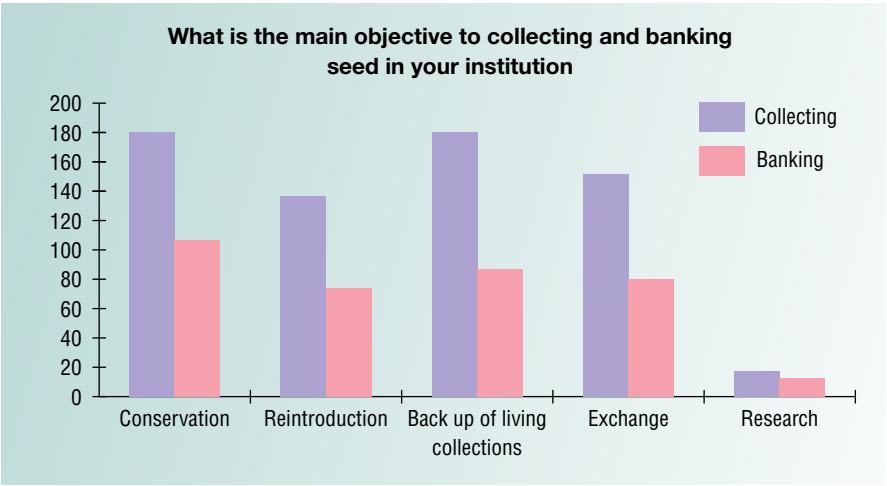


Figure 4. Number of institutions collecting and banking for various different objectives

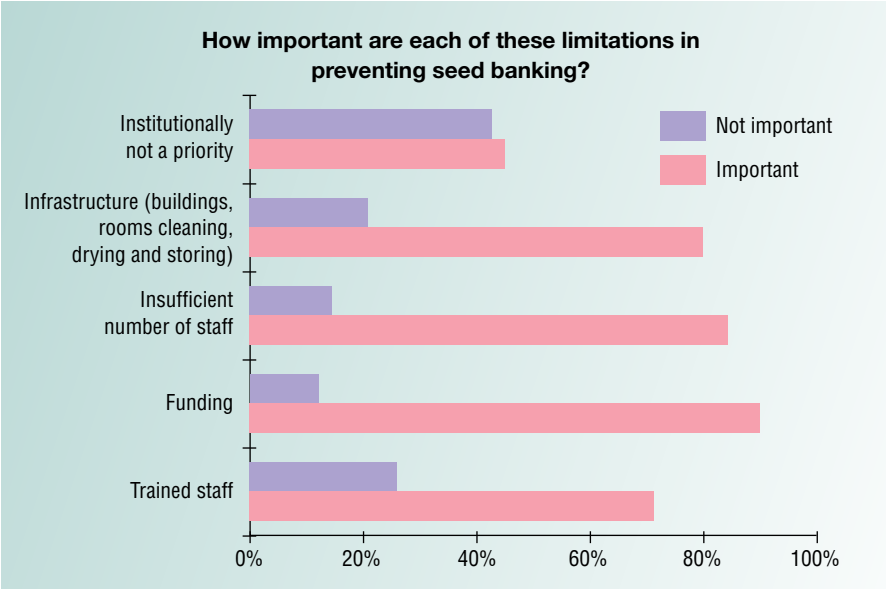


Figure 5. The importance of limitations in preventing seed banking

Seed collecting along Wheeler Pass Road, USA (Bureau of Land Management - Baker Resource Area, Seeds of Success)

Correctly identifying seed collections is essential if the seeds are to be utilised. Voucher material such as herbarium specimens should be collected at the time of seed collection in order to accurately identify seeds to a particular species. A third of the respondent institutions do not use voucher specimens to verify collection names.

It is advisable to store a duplicate accession of banked seed at another institution as an insurance against loss. Nearly two thirds of the institutions that answered this question do duplicate their collections.

Networking

Only half of the survey respondents reported being part of a seed banking network (57%). These included international networks such as the MSBP; regional networks such as ENSCONET and national networks, such as the French Conservatoires Botaniques Nationaux, the Center for Plant Conservation (US) and the Red Argentina de Bancos de Germoplasma de Especies

Global Tree Seed Bank Project:
A partnership between the Royal Botanic Gardens Kew Millennium Seed Bank Partnership and the Global Trees Campaign

In 2014, the Royal Botanic Gardens Kew Millennium Seed Bank Partnership secured a grant from the Garfield Weston Foundation for a four year project to bring an additional 3,000 tree species into secure *ex situ* collections at the Millennium Seed Bank (MSB). To help achieve this ambitious task, Kew has partnered with the Global Trees Campaign.

The Global Trees Campaign (GTC) is a partnership between BGCI and Fauna & Flora International, launched in 1999. The GTC works with botanic gardens and *in situ* conservation partners around the world, to deliver training and set up practical conservation projects to safeguard threatened tree species from extinction.

Contributing to the Global Tree Seed Bank project, the GTC will collect seed from hundreds of priority tree species, with a focus on threatened and highly utilised tree species. Working with our international network of partners, we are identifying which species to collect from and delivering training to ensure high quality of collections. We will launch seed collecting programmes during 2015. Training has already started in Kenya and Uganda, and further activities are planned for Belize, Tajikstan and Vietnam, among others.

As part of this project, the Global Trees Campaign is also undertaking a global survey of Critically Endangered (CR) and Endangered (EN) tree species held in *ex situ* collections. A global list of CR and EN tree species is being compiled from various resources, including the IUCN Red List of Threatened Species™ and national red lists. This list will be compared with records held in BGCI's PlantSearch database and the MSB Data Warehouse, to deliver the first global analysis of *ex situ* collections of CR and EN trees. The survey will identify seed bank and living collections, and will highlight threatened trees that are currently lacking protection through *ex situ* conservation. The results will be made widely available and will inform future collecting programmes by botanic gardens and seed banks worldwide.

The outputs of this project will step up conservation for some of the world's most threatened tree species, and will prepare for recovery and restoration programmes to take place in future.

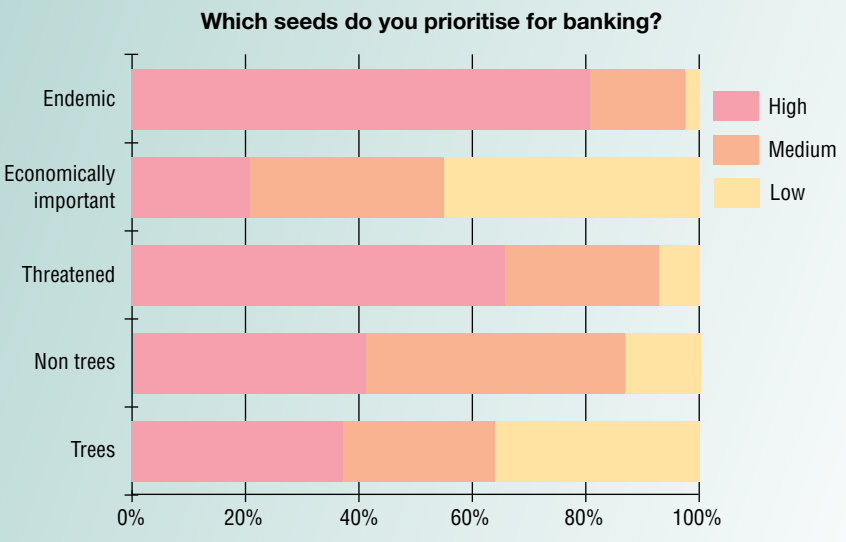


Figure 6. Species prioritised for banking

Inga edulis *seeds, Kisantu Botanic Garden (Paul Latham)*

Vegetales Nativas (Argentina). Of the institutions that are not part of a seed banking network, 90% agreed that they would benefit from being involved in one.

"*We'd love to help, but don't have the resources to be that helpful. Many regional botanic gardens are not equipped to be part of this worthy initiative. We'd be happy to facilitate your organisation in collecting seed from around Bendigo though.*" Brad Crème, Bendigo Botanic Gardens, Australia.

Objectives and limitations

The main objectives for survey respondents to collect and bank seed are generally the same. Most collect and bank seed for conservation and as a backup or to replace living collections. Reintroduction and exchange (*index seminum*) are also important. Several institutions collect and bank seed for research purposes (Fig. 4).

For institutions that are already banking seed there are several limitations to increasing this activity. These include factors such as infrastructure, human resources and funding. Lack of institutional priority was generally less of a limitation (Fig. 5).

"*One limitation is national and international support. We need BGCI and MSBP to help us with advocacy*" Tom Myers, Dunedin Botanic Garden, New Zealand.

Collected seed (Washington Rare Plant Care and Conservation Program, Seeds of Success)

Botanic gardens that collect and bank seed prioritise endemic and threatened species which are not trees. There is less emphasis on conserving trees and economically important taxa. This is not surprising as tree species usually require specialist equipment for seed collection (Fig. 6).

"*We focus on rare genotypes or disjunct populations and range extremes*"
Ethan Kauffman, Moore Farms Botanical Garden, United States

Discussion

Through the survey, we have identified a number of institutions involved in seed banking that were not previously documented in BGCI's databases. In order to be able to accurately monitor and measure the botanic garden community's extensive contribution to Target 8 of the GSPC, *ex situ* seed collections must be well reported.

The results of the survey suggest that at least a further 17,000 taxa are being conserved as seed in botanic gardens around the world than we were previously aware of. We cannot currently determine whether or not these accessions are unique taxa as information is not available in BGCI's databases.

Incorporating this data into PlantSearch would be the first step to determining which threatened and orthodox species are not in *ex situ* seed collections. Currently only a limited number of institutions that are involved in seed banking upload their seed accession data to PlantSearch. By uploading seed accession data, progress can be reported and priorities set.

Documentation is important not just for monitoring progress against targets but it is also essential for ensuring *ex situ* collections are available for research, reintroduction and restoration.

If seed collections are to be of conservation value, the protocols used for banking must be of a high standard. The survey indicates that some gardens could benefit from implementing higher standards for post-harvest seed handling in order to ensure that the viability of their seed is maintained. Drying and storing seed in air tight containers is important as damp seed quickly loses viability. Furthermore, if seed accessions are not verified with a herbarium voucher, their use for reintroduction, restoration and research is limited. Duplication of accessions is also important for safeguarding the collections.

Finally, we can say that through the survey, we have identified a number of strengths and a number of weaknesses in relation to seed banking in botanic gardens. Our aim now is to build on the strengths and address the weaknesses as we engage the whole community in trying to achieve GSPC Target 8 by 2020.

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INCREASING *EX SITU* CONSERVATION EFFORTS IN CALIFORNIA

Sand dunes at Punta Mazo, northwestern Baja California, Mexico (Evan Meyer)

The California Plant Rescue project is seeking to seed bank the entire flora of California and set up monitoring programs for rare taxa.

Introduction

The California Floristic Province (CFP) is one of the most botanically diverse and threatened regions in North America. The CFP, defined as the Mediterranean climatic region along the Pacific coast of the United States and Baja Peninsula of Mexico, is ranked as a global biodiversity hotspot (Myers *et al.*, 2000). Compared to many other parts of the world, large scale human development and landscape conversions to the CFP are relatively recent. In 1850, the United States census recorded fewer than 100,000 residents in the U.S. state of California; today, the human population in California is approaching 40 million (U.S. Census Bureau, 2014). This rapid influx of people has had a tremendous negative impact on the region's biodiversity. Many wildlands and the unique species contained within them have been converted to residential, agricultural and industrial landscapes. In the face of this pressure, extensive efforts to protect the wild landscapes and natural resources of California have been mounted. A network of federal, state and other land conservation jurisdictions manage roughly 45% of the state's lands with varying degrees of protection from development (Orman and Dreger 2014). The fight to protect land and *in situ* habitat is ongoing and in need of greater biological study; many lands which are considered protected still face threats to their biodiversity.

Development of *ex situ* collections

Some of the earliest plant specimens collected by a western botanist in California come from the Scottish explorer, David Douglas, who made the treacherous journey to the West Coast in the early 1830s and collected many plant species that were new to science at that time. As the United States expanded its borders into the western frontier during the 19th Century, scientists in turn enriched their knowledge of its biodiversity. By the early 1900s, herbaria and scientific institutions were established in California, and the unique plants of the region were being grown in botanic gardens both locally and around the world.

These ongoing plant collections have organically led to the existence of substantial *ex situ* living collections of the California flora. More recently, in response to declines of many California plant species due to loss of wildlands and their degradation through such factors as invasive species proliferation and climate change, the building of well-documented and genetically diverse wild germplasm collections of the rarest plants has been a conservation priority. A number of organizations maintain germplasm of California native plants. Rancho Santa Ana Botanic Garden (RSABG), located in the city of Claremont in eastern Los Angeles County, maintains one of the largest collections of native California seeds.

*Cushenbury Buckwheat (*Eriogonum ovalifolium *var.* vineum*) in the San Bernardino Mountains of southern California (Evan Meyer)*

Box 1. California Plant Rescue Partners as of December 2014.

- Center for Plant Conservation
- California Native Plant Society
- Rancho Santa Ana Botanic Garden
- Santa Barbara Botanic Garden
- University of California Botanical Gardens and Arboreta (Berkeley, Davis and Santa Cruz)
- San Diego Botanical Garden
- East Bay Regional Parks District

Currently, the RSABG seed bank contains more than 4,600 seed accessions representing over 1,900 taxa. Seeds are maintained at low humidity in -23°C freezers. The geographic scope of the RSABG collection encompasses the entire state of California as well as the Mexican portion of the CFP. Particular emphasis is placed on the rare plants of Southern California. Genera and families of particular diversity in the collection include *Astragalus* (Fabaceae), *Penstemon* (Plantaginaceae), *Clarkia* (Onagraceae) and the Polemoniaceae. The earliest collections have been stored since the late 1970s, and collection efforts are ongoing, with approximately 150 new accessions added each year. All collections of rare taxa are split into multiple seed lots, with a backup sample of each stored at the National Center for Genetic Resource Preservation (NCGRP), the United States federal germplasm collection.

A bias in past collection efforts

Environmental protection laws in the United States and the state of California require mitigation efforts when legally protected threatened and endangered (T&E) species are being disturbed or extirpated. These efforts often include seed banking as a component of the overall mitigation plan. Through agreements with the United States Department of Fish and Wildlife Service (USFWS) and the California Department of Fish and Wildlife (CDFW), seed banks are regularly utilized as *ex situ* storage facilities for T&E species. Largely due to legally mandated salvage and protection of T&E species, a substantial portion of these taxa are stored in *ex situ* germplasm collections, including the RSABG seed bank (Fig. 1; Meyer *et al.*, 2014). These seeds, some of which represent populations which have been extirpated from nature, comprise a genebank of immense value, but represent a limited subset of the overall CFP diversity.

While regulatory processes have resulted in a significant portion of rare taxa being banked, there are many rare taxa in California which lack legal T&E status, and thus are not required to be seed banked if they are impacted or destroyed during development. The California Rare Plant Rank (CRPR), a rarity index maintained by the CDFW and California Native Plant Society (CNPS), lists a total of 2,343 taxa of conservation concern (CNPS, 2014), while the combined number of plants with Federal and and/or State legal status is only 284. Of the rarest extant taxa (those that are classified as 1B by the CRPR), only 30 percent have been conserved in *ex situ* collections, in comparison to 71 percent of those with federal T&E status (Fig. 1). The Global Strategy for Plant Conservation (GSPC) Target 8 sets a goal of securing "at least 75 percent of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20 percent available for recovery and restoration programmes" (CBD, 2014). This target is well within reach for legally protected taxa in California, but remains far from realized for rare plants without legal status.

New initiatives for plant conservation

In the past year, a collaborative effort has been developed to reach *ex situ* conservation goals in California. This project, known as the California Plant Rescue, includes a variety of conservation organizations, botanic gardens and seed banks (Box 1).

*Coast barrel cactus (*Ferocactus viridescens*) in fruit (Evan Meyer)*

Figure 1. California Floristic Province Seed Bank coverage by rarity and legal status as of December 2013.

Rarity/Legal Status	Taxa Banked	Total Number of Taxa	Percentage Banked
All CRPR Ranked (excluding 1A and 2A)	514	2283	23%
CRPR Rank 1B	345	1143	30%
CRPR Rank 2B	41	495	8%
CRPR Rank 3	5	67	7%
CRPR Rank 4	123	578	21%
FESA or CESA Listed	167	284	59%
CESA Listed	124	218	57%
FESA Listed	138	195	71%

Figure 1 is adapted from Meyer *et al*.,2014. CRPR: California Rare Plant Rank (CNPS 2014), FESA: Federal Endangered Species Act, CESA: California Endangered Species Act.

Still in the organizing stages, the California Plant Rescue is seeking to seed bank the entire flora of California and set up monitoring programs for rare taxa. This is a lofty goal, and as the project begins, the immediate focus is on building seed collections of rare and threatened plants which have yet to be seed banked. As part of this collaboration, the California Plant Rescue has examined data from seed collections both in and out of California to create a list of existing seed accessions for California rare plants, and to identify gaps in germplasm collections which need to be filled (Meyer *et al*., 2014). We hope that this proactive approach will allow us to strategically focus and achieve goals which have not been met with legally mandated germplasm salvage.

Also of great concern to the California Plant Rescue and the RSABG seed bank is the flora of Baja California, Mexico. The northwestern portion of the state is part of the CFP and shares some floristic features with southern California. Like its northern counterpart, the flora of this region contains many endemic species and is also declining due to development and land conversion. In collaboration with Mexican federal agencies and NGOs, the California Plant Rescue plans to add northwestern Baja California to its target seed collection area.

The California Floristic Province presents an exciting opportunity for both conservation and restoration of its unique biodiversity. While threats continue to loom in the region, work continues to conserve land and develop germplasm collections of the rarest botanical diversity. It is our hope that the California Plant Rescue collaboration will greatly accelerate progress in building *ex situ* collections of the unique plants of this region.

Acknowledgements:

I would like to thank Naomi Fraga and Nick Jensen, who coauthored a peer reviewed paper with me from which much of this article is adapted. I would also like to thank Abby Hird, Loraine Washburn and Naomi Fraga for reviewing an early draft of this article and providing useful suggestions.

Seeds of Xylorhiza cognata *(rare, threatened or endangered in California and elsewhere), no legal listing status (John Macdonald)*

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The Ventana Wilderness in the Santa Lucia Mountains of the central coast of California (Billy Sale)

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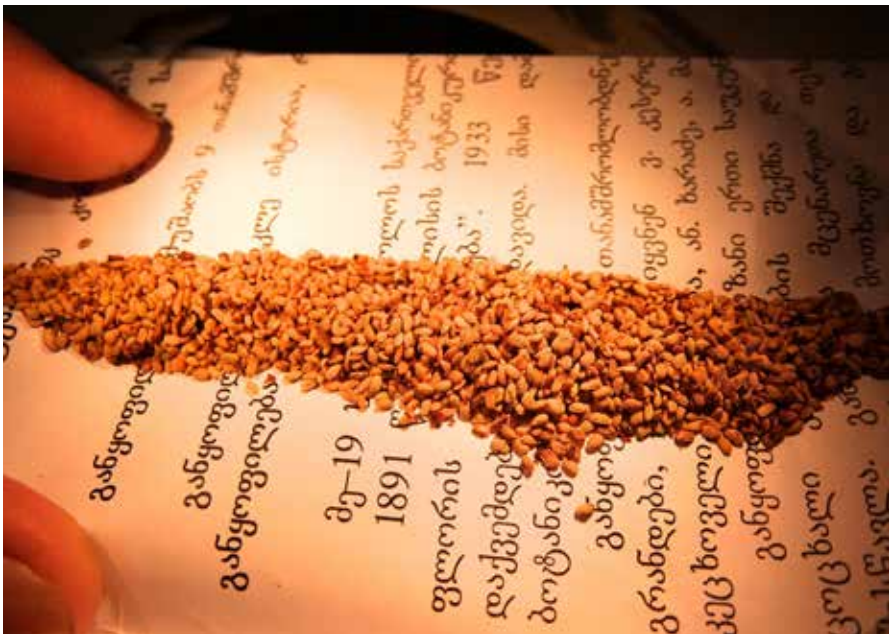
SEEDS FOR TOMORROW'S WORLD



Inspection of Rubus *spp. seed packet (K. Lewis-Jones)*

What future awaits the seeds that you save? An opportunity to contribute your thoughts to anthropological research and an original piece of artwork reflecting on what it means to save a seed.

Introduction

There is something very powerful about a seed. Even before you start thinking about the burst of vibrant green life it holds within it, the seed presents us with a delectable object; an often beautiful and always intriguing, perishable, organic capsule.

The collection of seeds lies deep at the heart of a long historical relationship between humans and plants and the practice has changed both them and us beyond recognition. Now, as we find ourselves in a time of great uncertainty in which habitats and processes that we have taken for granted face imperiled futures, this historical intimacy offers hope for the future in a new way. Plant conservation is a response to this insecurity – to the vulnerability both of the species at risk and for the people contemplating what it might mean to live in a world without them. Conservation aims to keep our options open, avoid catastrophes and enable us to better manage our relationship with the environment.

"Collecting seeds seems to be more than just a pragmatic and efficient solution to an uncertain future. It builds on a long legacy between humans and plants. It is a promise."

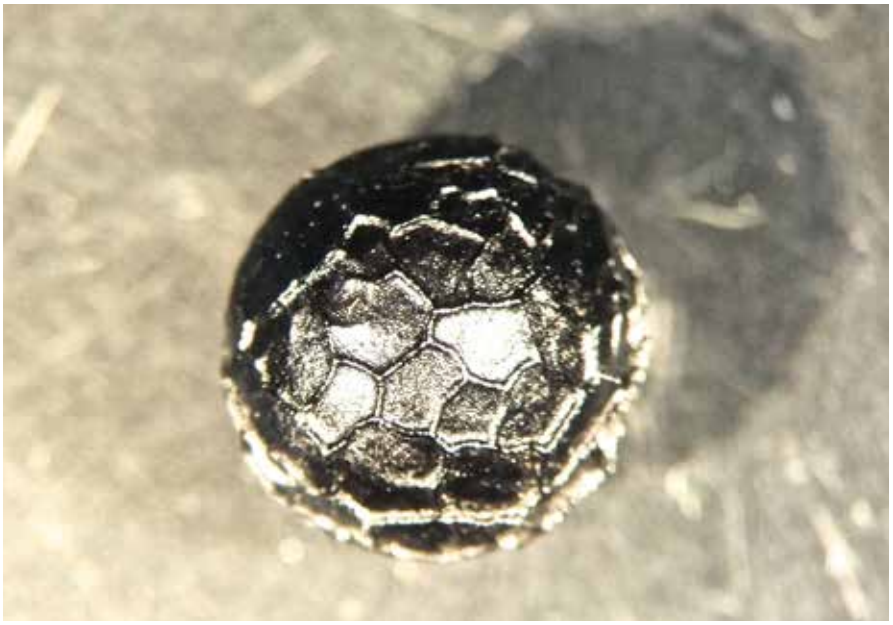
All the flowers of all the tomorrows are in the seeds of today.
Indian Proverb

Imagination and values

Seeds are the point in a plant's life when it can travel not only though its environment - by drifting, floating or catching a ride - but also through time; sleeping through long winters, or waiting until its patch in the sun opens up. Recently a cache of seeds from 32,000 years ago was used to successfully grow a *silene* plant (Kaufman, 2012). This biological 'sleeping beauty' capability has helped plants to cover the world, and means that for many plant species seeds make the perfect material for conservation (Li and Pritchard, 2009). Alongside this material suitability, however, there is another dimension that makes seeds ideal for conservation: their symbolic potency. Seeds represent an enticing pause that inspires us to reflect upon our place in history and the continuation of life into the future. They capture the imagination of children and adults alike – and imagination is a powerful thing.

Engaging with the public's imagination is at the heart of the work of many botanical gardens today and one of the best ways to engage people with environmental causes is through encouraging personal, emotional relationships with the natural world around them (Anderson, 1996). People respond in different ways to the perception of an imperiled future and for many the concept that the world is facing unknown changes is too big to fathom, or perhaps too daunting to act upon. Many people are simply unaware of the scale of the threat that plants face. And for those that are aware their knowledge and response to this knowledge varies hugely.

As an anthropologist, doing PhD research on the Millennium Seed Bank Partnership (MSBP) with the Royal Botanical Gardens, Kew, one of the



Single magnified seed of Paeonia mlokosewitschii *(K. Lewis-Jones)*

things that intrigues me most about seed conservation is the combination of collaborative passion and internal diversity. The Millennium Seed Bank opened in 2000 and works with partners across 80 countries, forming one of the world's largest *ex situ* plant conservation networks, collecting and conserving the seeds of threatened wild plants.
My research explores how the people who work in the partnership talk and think about the value of the seeds, and it has taken me from mountaintops to research laboratories. This last summer I spent 6 months with the seed conservation team in the Republic of Georgia – which has some of the highest levels of endemic plants in the temperate zone. The National Botanical Gardens of Georgia have been a partner of the MSBP for almost 10 years, during which time they have deposited the seeds of over 1,000 species. Next year I will be building on the fieldwork and interviews I carried out there by extending my research to the work of several partners that contribute towards the Seeds of Success programme in the United States. (I aim to gather thoughts and reflections from throughout the partnership and if you, or your institution, would like to find out more about how you can contribute to my research please contact me via the email below.)

Diversity and resilience

What makes plants important and valued by people within conservation is something which can often go unquestioned, or be translated into simple words, such as 'useful', that may not do justice to the complexity of how people feel and why they do what they do (Sandbrook *et al*., 2011). Personal, cultural, professional and environmental contexts mean that for all of the shared values of plant conservation, there is also a wonderful and important array of diversity.

Just as with genetic diversity, cultural diversity and value plurality provide vital versatility and resilience, something that is especially important in times of uncertainty and rapid change (Keulartz, 2007; Brosius, 2006). Because of this, the social sciences can make important contributions to conservation (Milton, 1996; Orlove and Brush 1996). They can offer a space for reflection and enable better understanding of why things are done. They allow us to develop ways of being more efficient, more guided, engaged and more imaginative, and call upon us to share - and to question - our assumptions. Additionally, by studying why people are interested in plant conservation we are in a better position to extend the appeal to people beyond.

For an anthropologist, conservation is particularly culturally interesting because it initiates intentional environmental interventions; ideally at a rate fast enough to combat the undesired and unintentional ones (Marris, 2011). This accelerated rate of change often happens within tight knit scientific and botanical communities and sometimes communication with the outside world can be sidelined or uninviting, especially when time is limited. On top of this, science calls for a professional objectivism which means that, at times, the kind of personal, ethical and social considerations that might usually go alongside imagining the future are relegated (Noss, 2007). Reflection on what our short and long terms goals are, however, is pertinent in something such as seed conservation. The seeds become a global conservation resource and how, when and why they leave the bank to fulfill their promise and become plants again becomes a human decision: something that, for some of these wild species, may be a matter of survival in the most final sense.

As we take upon ourselves the responsibility and role of stewards it demands us to reflect upon the values that guide us and what we hope to achieve. The global conservation of wild plant seeds provides an important and exciting opportunity to reimagine our relationship with the environment, to

Identifying a Betulus *spp. (K. Lewis-Jones)*

Collection of Carduus hohenackeri *seed heads (K. Lewis-Jones)*

create more sustainable interactions and to make sure there is space for keeping plant species alive, for their own sake, for environmental integrity and in a way which extends beyond the concept of human resource.

Diversity of values is important for keeping the future open to different potentials. We need to make sure we not only pay attention to, but also celebrate the diverse ways of thinking about and communicating the value of plants and seeds (Brosius and Hitchner, 2010; Keulartz, 2007). If we convert seeds into a functional human resource in our imaginations and in the way we communicate the value of plants to one another then that is all they will become (Collar, 2003; Sullivan, 2009). We have to engage both those involved in conservation and the public in discussions surrounding the bigger picture of why we conserve seeds – in order to leave the future open, diverse and, ultimately, resilient.

Inspiring symbols

Although *ex situ* conservation may not offer as many immediate points of interaction with local communities and the public as *in situ*, discussion and engagement is still important. The public must be engaged, not only for their support, but because care for the environment should not be just left to the 'experts'. The public should not feel that environmental responsibility has been designated to others, but it should be something that is culturally present. Seeds and their symbolic diversity, their intriguing, tangible nature, are perfect conceptual tools for reflecting upon the future. The work of artists such as Rob Kesseler, Dornith Doherty and Sophie Munn, who have all worked with seed banks and responded in striking, haunting and beautiful ways to the seeds within them, are testament to the power of the seed to inspire.

My research is about what it means to save a seed; what it means for us as individuals involved in the process and what it means in a wider sense, to have gathered this timely and important natural bounty (Barlow, 2000). Whether you are involved in seed conservation already, or are thinking of beginning,

"I would love to hear your thoughts on what kind of future you imagine awaits the seeds that you save".

In the spirit of celebrating this diversity and as part of my research I will be collaborating with the visual artist behind the 'homage to the seed', Sophie Munn, to generate a piece of work in response to your contributions and ideas.

To contribute and be involved please contact me at kayevelina@outlook.com

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DESIGNING SEED BANKS FOR *IN SITU* CONSERVATION PURPOSES: MORE SPECIES OR BETTER QUALITY?

A KEY STRATEGIC ISSUE FOR THE REINTRODUCTION OF RARE SPECIES INTO THE WILD

Introduction

The Fédération des Conservatoires botaniques nationaux (FCBN) brings together eleven Conservatoires botaniques nationaux (CBN) in a network of more than three hundred employees, seven conservatory gardens and nine seed banks dedicated to the conservation of wild species in France, including the overseas territories (see Map 1). With forty years of field expertise on species distribution[1], conservationists of this network are now able to identify species on the brink of extinction, and to undertake a combined approach between *ex situ* and *in situ* practices to address this potential loss of biodiversity.

From the seed bank to the field: a case study in the CBN of Brest

The seed bank of the CBN, Brest contains 1,165 threatened plant taxa categorized by IUCN as EW (Extinct in the Wild), CR (CRitically Endangered), EN (ENdangered) and VU (VUlnerable). These species mostly originate from the Mediterranean basin and oceanic islands around the world, notably the Canary, Mascarene and Juan Fernandez Archipelagos. Seeds are preserved in freezers at -18°C. Dedicated to the world's endangered flora, this seed bank is among the world's largest according to the number of species it harbours. Created in 1975, the CBN of Brest was indeed a pioneer in this field, committed since the beginning to the *ex situ* conservation of the world's threatened species.

Seeds for the future (S. Bourd)

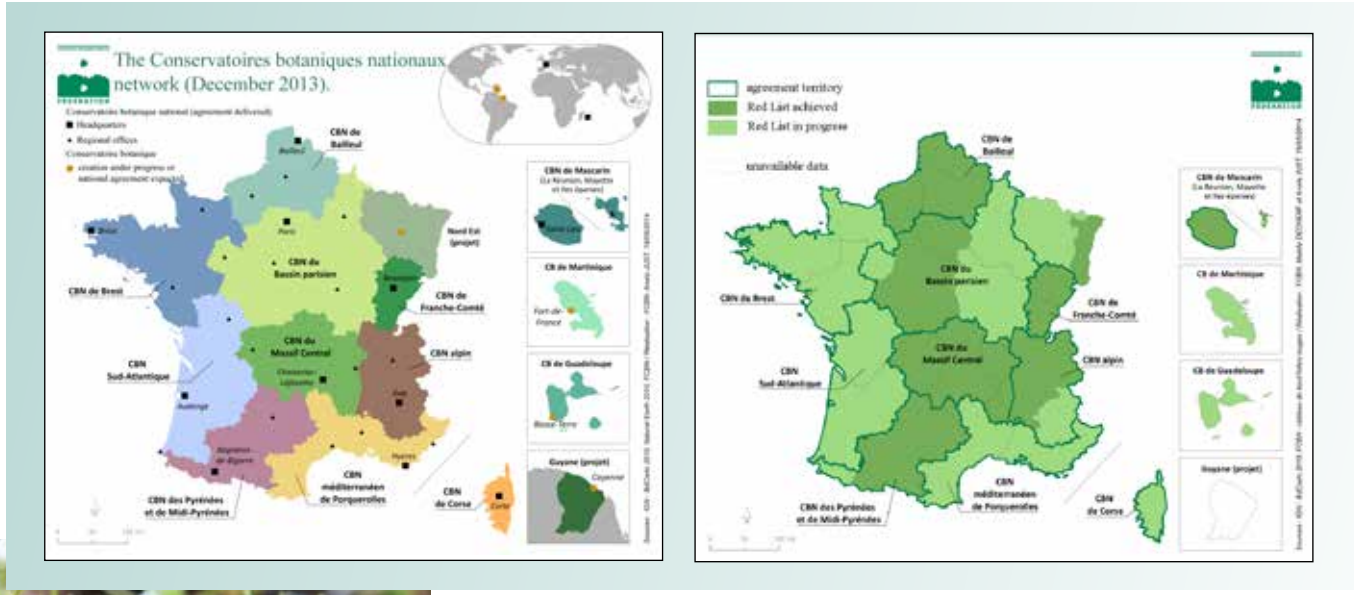
Arenaria grandiflora (P. Bardin)

The frozen seed collection is not an achievement in itself, but an essential tool for conservation actions, specifically *in situ* reintroduction or population reinforcement. For 40 years, a number of actions have been carried out from this collection of taxa to be restored in *natura*.

Among these species, *Normania triphylla*, an endemic species of Solanaceae from Madeira is noteworthy. The *Normania* genus is represented only by two species: *Normania nava*, an extinct endemic from Tenerife, Canary Islands, and *Normania triphylla* from Madeira, believed to be extinct since the last century until the botanist M. Nobrega found a few survivors in the Laurisilva in 1994. This extremely rare species suffers from strong competition of invading plants which overwhelm the few open areas of this subtropical forest. Twenty four seeds were handed to the CBN of Brest, who started an *ex situ* conservation programme, followed by *in situ* reintroduction, with the support of a private company.

The production of *Normania* plants began in July 2007 from a batch of a hundred seeds kept in the CBN freezers. In the spring of 2008, the number of adult plants for seed production and cuttings passed one hundred. Between 2007 and

[1]See the web platform of the French Flora Atlas at www.fcbn.fr



Above left: Map 1: The Conservatoires botaniques nationaux network
Above right: Map 2: Status of the regional Red Lists project (May 2014)

Seedlings of Bassia laniflora *(David Tatin / Orbisterre)*

2010, 80,000 *Normania triphylla* seeds where harvested in Brest's greenhouses, 30,000 of which were sent to Madeira. Those were sown in cultivated areas, around 19 foresters' houses within the Laurisilva, as well as in experimental sites in the wild. The aim of these forest nurseries was to obtain small cultivated populations in the mountains, in order to have a sustainable supply of accessible resources which could be progressively returned to the wild, in sites most favorable for the species establishment.

In 2010, reintroduction actions were carried out in the most favorable sites, in partnership with the Rui Viera de Funchal Botanical Garden, Madeira National Park and local schools. The success of the reintroduction of a species extinct in the wild requires some time and monitoring is underway. Nevertheless in 2013, new populations of *Normania* have been confirmed within and surrounding the testing sites.

This experiment highlights the importance of setting up *in situ* nurseries close to suitable habitats of the threatened species, partially due to the uncertainty of seeds maintaining high germination capabilities over a long time period during the banking process, and the risk of unwanted selection when species are cultivated in glasshouses and botanical gardens (Fridlander *et al*., 2000).

The need to resort to seed banking to protect wild species in the field is controversial, as this approach highlights. Amongst other issues, it does not address the continuing disappearance of wild species due to the many changes and misuses of their habitats. Furthermore, evidence indicates that climate change will disrupt distribution patterns for species, with consequent changes to the composition of plant and animal communities (Parmesan *et al*., 2002). However, as shown for *Normania triphylla*, genetic resources that have previously been seed banked are important to save species locally threatened with extinction, on condition that the habitat is still suitable to host the species. We do however advise considering the following point in order to successfully undertake reinforcement or reintroduction programmes in the future.

Can we trust admixtured populations to solve genetic issues?

Using allochthonous genetic resources to save local species has always provoked a strong debate. Under the precautionary principle, scientific authorities and public policies advocate only the use of local genetic material or express unambiguously

The Conservatoire botanique méditerranéen of Porquerolles reintroduces seedlings of Bassia laniflora, *a threatened species of the Provence region (David Tatin / Orbisterre)*

Seeds stored in the seed bank (Ca M'intéresse)

this preference by highlighting the risks of using non-local genetic materials. In the same way, land managers and local communities are reluctant to host genetic resources different from those that are locally threatened, mainly because they consider that the population used to bring 'new blood' to the threatened population is a population of a distinct taxon (Maurice *et al*., 2013).

However, in some cases, the level of genetic diversity among the threatened population is extremely low and the high risks of failure strongly promote the introduction of new genetic material into the depreciated populations (Bottin *et al*., 2008).

The reintroduction of the large-flowered sandwort in the Fontainebleau forest (*Arenaria grandiflora* L.), recently led by the CBN of the Paris Basin and the CESCO team of the National Museum of Natural History located in Paris, is an innovative approach to test the benefits of mixing plants of different origins in order to restore a threatened population of this mountain species in the lowlands. In 1999, genetic investigations gave evidence of inbreeding or fixation of deleterious alleles by drift in the remnant Fontainebleau population. Thus, it was proposed to save this severely declining species in the lowlands by not using local genetic resources with low fitness and inability to adapt but instead promoting an increased level of genetic diversity in the population to be reintroduced. A ten-year experiment in mixing populations started in 2001 in the Fontainebleau forest. It was conducted in several 100 m² enclosures, sufficiently distant from the native population to avoid any cross pollination and seed dispersal that may have interfered. The experimental populations were composed of native individuals and individuals of the nearest lowland population, in the Loire Valley.

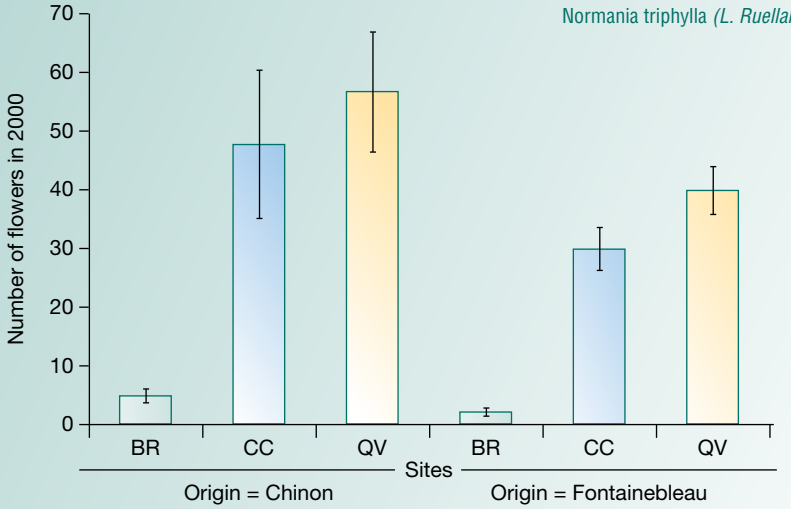
Ten years later, this experience has provided evidence that admixture has occurred in a positive way, with more vigorous individuals that exhibit a large number of flowers in the enclosures. Finally, in 2011, the mixed population was reintroduced into the native area where the original population had disappeared. The whole experiment is still being monitored to assess both the model in the enclosures and the reintroduction trial of the mixed population.

Taking forward Target 8 of the GSPC.

According to the Target 8 of the Global Strategy for Plant Conservation (GSPC), by the end of 2020, *"at least 75% of the threatened plant species are in ex situ collections, preferably in the country of origin, and at least 20% are available for recovery and restoration programs"*[2], with a priority given to critically endangered species.

The CBN are currently and massively involved in the completion of Red Lists at a regional scale. These are important due to the distribution patterns of species over the whole French territory, and have hugely improved, mainly over the past two decades. These Red Lists provide a basis for a new strategy for seed banking and it is now possible to assess the implementation of this GSPC target with a high level of accuracy.

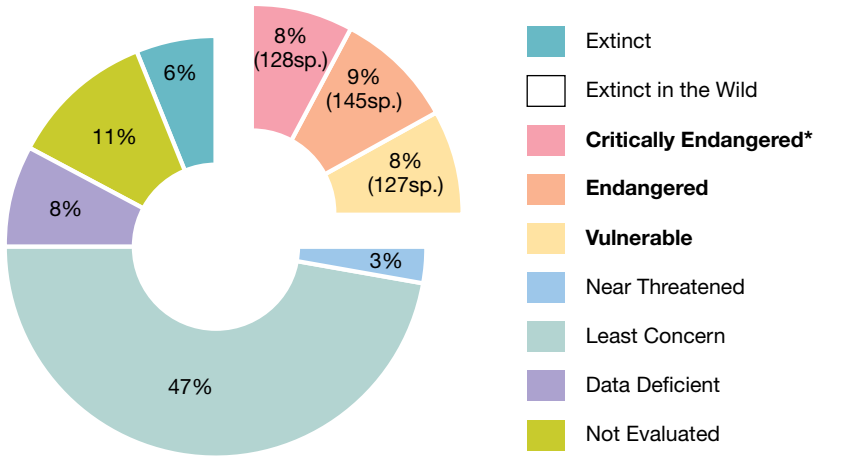
Normania triphylla *(L. Ruellan)*



The number of flowers (that is a component of fitness) is systematically higher in the enclosures (BR. CC. & QV.) for non-local origin (Chinon) than for local one (Fontainebleau). Only microsatellite markers, currently under development, enable to distinguish the origin of recruitment and to verify if this trend occurs in the offspring.

In Maurice *et al*., 2013.

[2]See www.plants2020.net



*in this figure, this class includes about twenty species CRitically Endangered but probably extinct.

Red List of the Ile-de-France region

Region	% of CR species seed banked
Bourgogne	16 (18 species of 112)
Centre	18 (27 species of 148)
Ile-de-France	55 (59 species of 108)

Implementation of Target 8 of the GSPC for the CBN of the Paris Basin, with focus on the CRitically endangered species.

For example, the Red List of the Ile-de-France region (Auvert *et al*., 2011) highlighted four hundred critically endangered species that conservationists must take care of, through *ex situ* and *in situ* conservation programs.

According to this review, one can consider that seed banking of seed from one location of those four hundred species is sufficient. However, the *Arenaria grandiflora* experiment clearly supports the idea that saving a species which is locally threatened with extinction will also need, in some cases, non-local genotypes. Because it is now possible to investigate genetic diversity rapidly and at affordable costs, seed banks must adapt and offer seed from different origins for species to be reintroduced or reinforced in the wild. People in charge of conservation programs should however take care of the ecological features of the habitats in which the seeds or cuttings are collected, to avoid any kind of outbreeding depression when this material is translocated into the population threatened with extinction. It is also important to investigate the genetic structure of the sampled population, for example when the founder effect leads to a patchy distribution of genetic diversity (Machon *et al*., 2003).

It is highly probable that a dilemma will soon emerge, in the context of limited resources dedicated to seed collecting, between banking seed from several locations of a regionally critically endangered species or focusing only on single locations, but for all threatened species. If the priority is given to seed banking all threatened species, any subsequent reinforcement or reintroduction programmes need to clearly understand the threats on the population in the wild and if the population on the verge of extinction is genetically depreciated. Then seed banking from several locations is an alternative pathway to consider.

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HAWAI'I ISLAND NATIVE SEED BANK

Seed banking is an important strategy for conserving species from Hawai'i's highly endangered ecosystems

Seeds of: Acacia koa, Erythrina sandwicensis, Mezoneuron kavaiensis, Sophora chrysophylla. *All are orthodox species (Tien Austin)*

Introduction

Hawai'i's native ecosystems are among the most endangered ecosystems in the world. For example, over 95% of Hawai'i's dry forests have been destroyed, and over 25% of the endangered taxa in the Hawaiian flora are from the dry forest. Habitat loss due to wildfires, ungulate grazing, and development continues to alter the landscape at an alarming rate. It is vital that the precious species of Hawai'i's dry, mesic, and wet forest ecosystems be conserved. Seed banking is an important strategy for doing this.

The Hawai'i Forest Institute, in collaboration with community partners, is working to mitigate and reverse the loss of native species and habitats through the Hawai'i Island Native Seed Bank. The Seed Bank enables project partners to store seed for the future and create a genetic safety net for Hawaiian species. Banked seeds can be used for broadcast seeding, performing restoration work, creating living fuel breaks, and conducting research. Seed banking has in recent years become an essential restoration and conservation tool.

Short term seed banking can be used for the preservation of scarce, endangered plants. Seed from species for which only a few individuals are left can be saved and propagated in the future. In fact, seed banking has saved a species: *Isodendrion pyrifolium* (a Hawaiian violet), the founders of which died due to drought but the seed from good seed years had been collected and stored. It is still possible to propagate plants derived from the seed of the deceased founder and therefore keep the genetic identity of that species alive.

Fire is a constant threat to native ecosystems in Hawai'i. Hawaiian plants have not evolved with fire (seed is not fire stimulated), so forests burn and native plants do not regenerate rapidly. Fire-adapted non-native species take over following fires and often alter the landscape forever. Seed banking – and subsequent reintroduction of native plants to burned areas through broadcast seeding or out-planting has become an essential tool for restoration following fire.

Over the past 20 years, seed on Hawai'i Island was mainly collected only to meet propagation needs for the current year. No seed was saved for the future. Because seed production and viability are sporadic from year to year, this means that seed may not be available or viable when it is most needed. For example, in 2010 a Hawai'i Island dry forest restoration project required 500

Hydrogen is a back up source of energy for the seed bank refrigerator (Tien Austin)

Dodonaea viscosa seedlings. Because 2010 was a drought year in Hawai'i, the 2010 seed had very low viability. Fortunately *Dodonaea* seeds had been stored from 2008 collections and they had very high viability. Thus the restoration goals could be achieved using the older stored seeds.

Seed Bank history and operation

In 2008, the Hawai'i Wildfire Management Organization (HWMO) provided start-up funding to help create the Hawai'i Island Native Seed Bank which is housed at Pu'u Wa'awa'a Ranch, on Hawai'i Island. Other funding has been received from the National Park Service and the U.S. Fish & Wildlife Service. In 2012 HWMO further supported the seed bank by providing funding to purchase a 10' x10' walk-in refrigerator. This refrigerator is operated with solar power and is in an enclosed building that has over 8 inches of insulation and an enclosed entry foyer, making it extremely cost effective to operate. The large size fridge eliminated the limitations that a normal size refrigerator imposed upon seed collection and storage. Now the Hawai'i Seed Bank is able to collect and save seeds without concerns about storage space.

Pu'u Wa'awa'a Ranch is home to a small off-grid micro grid at the base of one of Hawaii's most historic Pu'us (little mountain). The remaining 32 acre ranch headquarters of what once was a 110,000 acre cattle ranch is powered by an independent renewable energy system. The system consists of an 85 kW photovoltaic (PV) array and a state of the art Sony Energy Storage System (ESS). The Sony ESS provides the primary storage for powering the ranch at night, and in poor weather. The Olivine type, Lithium Iron Phosphate batteries are rated at 50 kilowatts of power with 110 kilowatt hours of stored energy.

Pu'u Wa'awa'a has a micro climate that usually results in cloudy overcast conditions by mid-day. The large PV array on the roof of the Energy Lab is designed to provide enough power to the daytime loads of the ranch in marginal weather, but during early mornings and exceptional days, there is an excess of solar energy being delivered. During these periods, the excess energy is routed to make hydrogen and stored for use later. The resulting solar hydrogen can be used to power vehicles, turned back into electricity with stationary fuel cells when the batteries are low, or used for cooking in place of propane. This system ensures that the maximum amount of solar energy is harvested at all times from the PV array.

All utility power lines and poles were removed to ensure the safety of the endangered Nene', (Hawaiian goose), that call the ranch and surrounding conservation land and reservoir home. Electrical power is now delivered throughout the ranch via underground transmission lines.

The Seed Bank's walk-in cooler is powered entirely by the power of the sun with clean renewable solar energy saving over $4,000 dollars per year on operational costs.

The seed collections are stored for seed bank partners on Hawai'i Island and all accessions are made up of Hawai'i Island native species. In cooperation with

Above right: Erythrina sandwicensis *seeds cleaned and ready for storage (Tien Austin)*
Above: (Tien Austin)

local, State, and Federal agencies, the Seed Bank collects and accepts seed from common as well as rare, threatened and endangered species. Collections of common species can be shared for restoration at various sites in need of seed, or saved strictly for the partner site. Each partner site specifies whether they want to save the seed for their own future projects or are giving the seed to be shared with other sites.

User fees for seed storage are minimal at $200/year for a 2'x3' cubic bin. This fee pays for seed drying, packaging, database management for the incoming collections throughout the year as well as long-term storage. Each user has their own bin so collections are separated by site. The Seed Bank also offers services such as viability analysis. Germination rate is determined at the time the seed is brought into the seed bank, after one year, five years and ten years, thereby establishing germination stability or decline in storage. Seed cleaning services are also offered. Seed bank personnel utilize a small machine that separates the seed from the husk. Another machine removes the husk so that what remains are clean seeds that are ready to be dried to 20% moisture level, packaged and stored.

In restoration work it is easy and practical for the site managers to monitor the flowering and seeding of plants in the field. Thus, seeds can be collected throughout the year. Common seed is collected in bulk and collectors note the number of trees that the seed was collected from at the site, as well as other pertinent collection information, such as date, and location information. Rare seed is collected by individual founder. These data help to monitor the genetics of species. The seed bank is a "working seed bank," which means that the seed is stored for up to 15 years under refrigeration. It is not intended to be a long term storage facility. The working seed bank model is one in which the seed is reintroduced into the environment as needed. It is cycled out into the field every year for 5-10 years (at the latest) for propagation or broadcasting. The idea is to collect more seeds than are needed for the current year and have them available for future restoration or research projects.

Seed bank Energy System Specifications:

- 85 kW Photovoltaic Array
- 50 kW / 110 kW Energy Storage System
- 40 kW dc to ac Inverter
- 1.5 kW Wind Turbine
- 12 kg/Day Hydrogen Electrolyzer w/ 25 kg of H2 Storage
- 6,000 psi H2 refuelling Station
- 12 kW Hydrogen Fuel Cell for Battery backup
- 75 kva Diesel Backup Generator for emergency use

Seed of Dodonaea viscosa. *The seed on the left has been cleaned, dried and packaged. The seed on the right is from the field. Small cleaning machines separate the seed from the husk (Tien Austin)*

Jill Wagner, Hawaii Seed Bank Coordinator, entering the fridge (Tien Austin)

The Hawai'i Island Native Seed Bank is a partner in a larger Statewide seed bank network; the Hawaii Seed Bank Partnership. Each of the main Hawaiian Islands has developed it's own seed bank. The Statewide Partnership comes together annually to work on seed banking issues such as; prioritizing research needs for Hawaiian species, developing standardized operational protocols, data management, and conducting research on rare and endangered species; creating duplicate collections within the State; creating conservation plans for Species of Conservation Importance; and networking with partners in the Hawaii Plant Conservation Network. The Hawaii Plant Conservation Network includes government agencies, conservation alliances, educational institutions, botanical gardens, micropropagation laboratories, nurseries, and other conservation groups.

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SEED CONSERVATION OF CHINA'S FLORA THROUGH THE GERMPLASM BANK OF WILD SPECIES

Carrying out germination tests at GBOWS (Germplasm Bank of Wild Species)

The Germplasm Bank of Wild Species is the biggest germplasm conservation facility for wild species in China.

Introduction

Ex situ conservation has been widely adopted as a plant conservation practice. Seed banking, as a cost-efficient conservation tool, was initially introduced for preserving crop seeds. Over the past 15 years, this "dry-out" and "freeze-up" seed conservation technique has been widely adopted in many countries to safeguard wild plant species, propelled by Millennium Seed Bank Partnership (MSBP) of the Royal Botanic Gardens Kew (RBG Kew).

The Germplasm Bank of Wild Species (GBOWS), was established in 2008 at the Kunming Institute of Botany (KIB), Chinese Academy of Sciences. It is the biggest germplasm conservation facility for wild species in China and host to China's biggest seed bank, playing an important role in the face of biodiversity loss due to dramatic environmental change and the fast-growing economy. As an *ex-situ* conservation facility located in a global biodiversity hotspot, it aims to address the loss of China's biological heritage.

Background

There are about 31,000 vascular plants recorded in China, of which around 50% can be found nowhere else in the world (Wu *et al*., 2013). China is also home to 7,516 vertebrates, including 1,269 different kinds of birds (Ministry of Environmental Protection, 2013). China harbors four of the 34 global biodiversity hotspots, in which the Mountains of Southwest China and the Himalaya are centers of distribution of many important species, e.g. Tibetan antelope (*Pantholops hodgsonii*), giant panda (*Ailuropoda melanoleuca*), rhododendron (*Rhododendron* spp.) and primrose (*Primula* spp.). The northern hemisphere's largest evergreen broadleaved forest

Collecting seed in the field (Germplasm Bank of Wild Species)

GBOW's cold room (Germplasm Bank of Wild Species)

ecosystem is located in south and southwest China, greatly contributing to the diversity of the country's flora and fauna.

However, China's wilderness and biodiversity are coming under increasing threat from rapid economic growth. Intensification of agriculture, large development projects, the over-harvesting of timber and medicinal plants all contribute to this threat. The conservation of China's unique genetic resources is therefore of great necessity and urgency to support the sustainability of the nation. The GBOWS project was conceived and proposed in 1999 by Prof. WU Zhengyi, a prominent botanist from KIB. It aims to preserve and carry out research on the germplasm of China's native plants, animals, microbes and fungi. The main building of GBOWS was built and functioning by 2008 with three preservation facilities—the seed bank, the *in vitro* plant germplasm bank and the plant DNA bank. The microbial germplasm bank and the animal germplasm bank are located at Yunnan University and Kunming Institute of Zoology, CAS respectively, as subsidiary sections of the GBOWS project.

Target and progress

The seed bank is the core conservation facility of GBOWS, with the target of preserving 100,000 accessions of 10,000 species from China by 2020. China's plant species that are threatened, endemic and economically important are prioritized for collection. By the end of 2014, GBOWS's seed collections reached 65,067 accessions of 8,855 species,

"30% of China's seed plants have been conserved in its national seed storage facility."

Conserved species have been collected from different climatic zones and vegetation types across China, from the arid Gobi desert to temperate forests in Northeast China, and from the Himalayan alpine scree slopes to tropical jungles. Of particular note are the 15,018 accessions representing 4,900 species that have been collected from the Qinghai-Tibetan Plateau. This is thought to be one of the most species-rich places in China, but also one of the most vulnerable to climate change. Tibet represents about half the size and includes all the landscapes of the Qinghai-Tibetan Plateau. Although there are more than 40 nature reserves established in Tibet, there are no botanical gardens or seed banks. The seed collection held in GBOWS is important to fill the gap in *ex-situ* conservation of Tibetan plants.

GBOWS's seed preservation facilities were designed and are managed according to international standards. Collected seed is dried in the drying facilities at a temperature of 15°C and 15% relative humidity and then sealed in containers or foil bags, before being transferred to the freezer-like cold room which is maintained at -20°C, for long-term storage. As the biggest regional seed bank for wild species, GBOWS is capable of providing seed storage services for its national and international counterparts (see Table 1) to back up their seed collections in a secure condition. By the end of 2013, 1,256 seed collections from several organizations in-country and abroad had been duplicated in GBOWS.

Networking and training

To preserve China's mega-flora and achieve the ambitious seed conservation target before 2020, GBOWS could not work alone. GBOWS has therefore developed a nationwide seed collecting network. This includes 71 organizations, research institutes, universities and nature reserves that are actively collecting seeds from their local flora for long term conservation. Furthermore, young researchers, forestry staff and students involved in seed collecting programmes are trained in seed conservation theory and techniques through regular training courses, workshops and field practice. In Yunnan province, more than 50% of the nature reserves have sent

GBOWs building (Germplasm Bank of Wild Species)

their staff to attend the annual "seed conservation techniques" training course. Through this, many *in situ* conservation practitioners have learnt about *ex situ* conservation theory and now understand the procedures of seed conservation. In the past 8 years, over 400 people have received seed conservation techniques training delivered by staff from GBOWS and its international collaborators including the Millennium Seed Bank Partnership.

Seed collecting in the field (Germplasm Bank of Wild Species)

Seed science research

The massive number of seed accessions held in the GBOWS seed bank counters the loss of China's plant diversity, it also provides a great opportunity to enhance understanding of China's plant resources through additional seed information, such as seed morphology, germination and dormancy. GBOWS's germination team generates data from around 8,000 germination tests every year, to monitor collection quality and improve species germination practices. Moreover, the seed biology research capacity at GBOWS was built up through studies of seed storage behavior, especially of threatened species. There are also comparative seed studies conducted in collaboration with other seed biologists worldwide. For example, it has been reported that seed collections from alpine regions in Europe are short-lived and can only survive in seed bank conditions for a few years. There is similar research work ongoing at GBOWS to verify this hypothesis with China's alpine species.

Future perspectives: DNA barcoding and seed collection

For best practice, it is important to have every seed collection verified with the accurate species name. However, this can sometimes be difficult if the taxonomic characteristics of the target species are not present when the seeds are harvested. It is even more tricky if the targeted species and its close-relatives exist in the same area. For example, *Pedicularis* is the third biggest genus in China with 352 species recorded in the Flora of China. Two thirds of these species can be found in the Himalayan-Hengduan Mts. Region. In the alpine meadows of northwest Yunnan, it is common to find different species of *Pedicularis* mingling together and more or less sharing similar phenology. It is very difficult to tell one from another during the seed collecting season. However, with the development of plant DNA barcoding techniques, it is possible to identify the seed collections by the use of molecular tools. The latest research on the DNA barcoding of *Pedicularis* by KIB's researchers found that it is possible to discriminate this big group at species level by certain DNA barcodes (Yu *et al*., 2011). This will make identification efficient and accurate and provide the seed collections with accurate names for future utilization. It is expected to expand the DNA barcoding techniques for verification of a greater number of seed collections.

Name of organization	Duplicated collection resources
Royal Botanical Gardens Kew	UK native species
World Agroforestry Centre	Tree species
Sichuan Agricultural Academy of Sciences	Forage species
International Center for Bamboo and Rattan	Bamboo species
Ling Yun chengsheng immortality Biotechnology Co. Ltd	*Dendrobium officinale*
Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences	Marsh plant

Table 1. Origin of seeds duplicated at GBOWS

Seed collecting training (Germplasm Bank of Wild Species)

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SEED BANKING IN THE CARPATHIAN BASIN: THE PANNON SEED BANK PROJECT

This project aims to ensure the long-term seed conservation of the wild vascular flora of the Pannonian biogeographical region, assisting and complementing *in situ* conservation.

Collection of seed samples of wild vascular plant species (Krisztián Halász)

Introduction

The main objective of the Convention on Biological Diversity is the conservation of the Earth's biodiversity. In responding to this, the European Union (EU) has developed an EU Biodiversity Strategy, which is implemented through the EU Biodiversity Action Plan. One element of this Action Plan is to identify and fill critical gaps in *ex situ* conservation programmes for wild species.

Furthermore, the Global Strategy for Plant Conservation, adopted as part of the CBD in 2002, has set a target that at least 75% of endangered species must be preserved in *ex-situ* collections, preferably in the country of origin, by 2020.

The Pannon Seed Bank

In compliance with the above, the main goal of this project was to create the Pannon Seed Bank in Hungary to facilitate the long-term seed preservation of the wild vascular flora of the Pannonian biogeographical region, in order to assist and complement *in situ* species conservation activities.

Precise documentation of the species being collected (Krisztián Halász)

In addition to the increased safety in case of accidental loss or degradation of endangered populations of rare species in natural, native habitats (Bölöni *et al*., 2007), *ex situ* seed banks may provide:

- additional possibilities for monitoring genetic changes in wild populations;
- facilitate access to research material without increasing the rate of disturbance of and pressure on the original habitats;
- assist multidisciplinary studies on factors involved in the maintenance of diversity and stability of plant associations.

Collectively, seed banks provide a valuable collection of natural assets, which are of great importance in conserving biodiversity at national, European and global levels and in helping to meet the 2010 and 2020 biodiversity objectives.

The seed bank project

The Pannon Seed Bank project (full title: *Establishment of the Pannon Seed Bank for the long-term* ex situ *conservation of Hungarian vascular wild plants*) was financed by the LIFE+ programme and co-financed by the Ministry of Rural Development of Hungary. The main objective of the project was to collect and preserve at least 800 species of the wild native flora of the Pannonian Biogeographical Region between 2010 and 2014 (Jalas *et al*., 1972-1999, Kurtto *et al*., 2004-2007, Tutin *et al*., 1964-1980).

Seed samples are saved in the Base and Active storage facilities of the Pannon Seed Bank established at the Research Centre for Agrobiodiversity at Tápiószele (RCAT) of the Central Agricultural Office; the man-made mine hole inside the Esztramos Hill of the Aggtelek National Park Directorate (ANPD); and at the Institute of Ecology and Botany of the Centre for Ecological Research of the Hungarian Academy of Sciences (IEB CER HAS) in the National Botanical Garden of Vácrátót. Expert botanists from IEB CER HAS and the Budapest Zoo & Botanical Garden elaborated and coordinated most of the collection activities, which were carried out with the involvement of botanists, local experts and rangers of the National Park Directorates.

Reintroduction of a sand steppe species to a Natura 2000 priority habitat was carried out to demonstrate the practical uses of surplus seed samples stored in the active seed bank. Ten species characteristic to Pannonic sand steppes and inland dune habitats are planned to be reintroduced to a 12 hectare site of ex-arable fields invaded by common milkweed (*Asclepias syriaca*) in the vicinity of the Fülöpháza Sand Dune Area of the Kiskunság National Park.

Seeds of Sanguisorba minor *(Krisztián Halász)*

The role of the National Botanical Garden of Vácrátót of IEB CER HAS in the project is important. It provides the site for one of the Active storage rooms, as well as for research in the reintroduction of species. The garden has the richest collection of living plant material in Hungary (13,000 taxa) and is an important *ex situ* site for preservation and demonstration. In 2007, Berkenyeház, an exhibition building which also houses installations of the Pannon Seed Bank, showing its objective and importance was opened.

Seeds of Carduus crispus *(Krisztián Halász)*

Seed collecting

The whole procedure of collecting seed samples (Brown and Marshall, 1995) of wild vascular plant species was carried out in compliance with the collection strategy and the seed collection methodology developed under the project, as well as under the strict control of the project and the coordination of the IEB CER, which is the most prominent national institute in vegetation mapping and botany-related issues, with long and in-depth experience.

Seed processing and storage work was carried out in harmony with the exploration and collection of seed samples.

A basic procedure was to accept seed samples into the Pannon Seed Bank complying with the following requirements:

- precise documentation of the species according to Király *et al*., (2009), habitat and collecting site;
- desired number and quality of seeds collected from a number of specimens adequately representing the population.

"Training sessions were organized for collectors to teach them the aims of the project and the process of collecting."

A large quantity of data was obtained during this work, and a well-built database was developed to handle this. Species identified for collecting from

the Pannonian biogeographical region were chosen primarily according to their storability (Schermann, 1966) . These characteristics resulted in a list of 1,841 collectable species of the total of 2,200 native vascular plant species of our country. 783 taxa of these have seeds with orthodox or orthodox/recalcitrant storability, 1,058 taxa are likely to have orthodox seeds or no literature could be found regarding their seed biology.

Seed storage

Once collected, seeds were rapidly transferred to receiving centres. After processing data and pre-cleaning, the seeds were forwarded to Tápiószele, where proper cleaning (according to the fruit and seed type), taxonomical identification and drying at room temperature were executed.

Seeds are packed in 3 layered moisture-proof, airtight containers. Seed samples are safeguarded in the Base (-20 °C) and Active (0 °C) storage facilities of the Pannon Seed Bank established at RCAT. 110 m³ of room is provided here. The Base collection serves the long term conservation of reserve samples, while the Active collection helps to facilitate research and the distribution of research material. In order to achieve full safety, a duplicate store of the Base collection (50 m³) has been established inside a man-made mine hole inside the Esztramos Hill of the Aggtelek National Park Directorate to avoid risks of unexpected environmental/technical hazards. The duplicate store (50 m³) of the Active seed collection is located at the Institute of Ecology and Botany.

Seeds are packed in 3 layered moisture proof, airtight containers (Krisztián Halász)

Berkenyeház, an exhibition building of the National Botanic Garden, which also houses installations of the Pannonian Seed Bank, showing its objective and importance (Krisztián Halász)

A total of 1,892 collections of 930 taxa have been processed during the 4 years of collection. Collections of 894 of these taxa were collected in an acceptable quality and quantity. A reasonably high number of protected and endangered species were also collected, thanks to colleagues from 9 National Park Directorates and 5 research institutes and universities. In addition, a number of individual collectors also contributed to this work. All collections were supervised by field botany experts resulting in a good ratio of excellent quality and quantity. 60% of collections contained the desired 5,000 seeds, 75% of them had 2,000 seeds and only 5% of the gathered seeds were contaminated or of low quality, thus not suitable for storing.

"By the end of 2014, 42.7% of protected and 61.7% of endangered species of Hungarian flora had been collected."

Further information is available from the home page of the Pannon Seed Bank: http://www.pannonmagbank.hu/pmb/

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Photos by Krisztián Halász, researcher and Éva Szakács, communication program manager at Institute of Ecology and Botany of Centre for Ecological Research of Hungarian Academy of Sciences (IEB CER HAS) in the National Botanical Garden of Vácrátót, Hungary. Krisztián Halász

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NASSTEC: A EUROPEAN PROJECT TO PROMOTE THE USE OF NATIVE SEEDS FOR GRASSLAND RESTORATION

Species-rich alpine meadow in the Dolomites (MUSE)

NASSTEC in a Nutshell	
Project type:	EU FP7 - Marie Curie ITN
Contract:	PITN-GA-2013-607785
Duration:	4 years: April 2014 - March 2018
Funding:	3.4 million Euros
Partners:	7 full partners + 7 Associate partners from 4 Member states: Italy, UK, Spain and the Netherlands

NASSTEC - what is it?

NASSTEC (The NAtive Seed Science, TEchnology and Conservation Initial Training Network) is an EU Marie Curie Initial Training Network that will train 11 PhD students at the initial stage of their research careers in native seed science, conservation and use. Like all Marie Curie actions, NASSTEC is designed to promote training of researchers and their transnational mobility, making research an attractive career for people in the early stage of their academic training.

There are 11 NASSTEC researchers at the moment, originating from 7 countries: Canada, Croatia, Italy, Sri Lanka, Spain, Portugal and the United States. According to the Marie Curie mobility rules they have to based in a country other than the one where they have spent the last three years.

An additional person will join the network in December 2015 as an experienced researcher - if you are interested look out for this position that will be advertised in mid 2015 on the NASSTEC website.

NASSTEC - The partnership

NASSTEC involves 7 full partners where the various researchers in the network are based: these include four academic institutions - MUSE - Trento Science Museum in Italy - as coordinator, the Royal Botanic Gardens Kew in England, Pavia University in Italy, the James Hutton Institute in Scotland and three native seed producers, two small companies: Scotia Seeds in Scotland and Semillas Silvestres in Spain and Syngenta Seeds in the Netherlands. Seven other

Community projects sowing native seeds in Scotland (Scotia Seeds)

institutions are associated with the project and contribute to the training and research of the students; these include Kings Park in Perth Australia, the Jardin Botanico Atlantico in Spain, the National Trust for Scotland, The European Research Agency in Rome, a local public Administration in Trento and two small companies of tourist and research services in Spain and in Scotland.

NASSTEC - The need

Habitat loss and degradation caused by human activity has led to an increased demand for native seeds for restoration purposes that is not met by an adequate supply in many countries. Large scale native seed production is now a significant challenge for native seed companies and one of the main constraints for effective habitat restoration. In Europe, native seeds are highly demanded for a wide range of grassland restoration activities such as those involved in roadwork, ski slopes, new buildings and quarries. Additionally the use of native seeds is mandatory in all Natura 2000 sites according to the EU Habitat Directive, and yet native seeds are not widely available in Europe. The market is underdeveloped and only small scale operations are active, detached from the academic sector and very often lacking baseline knowledge on key species, their biology and seed ecology. Commonly restoration is carried out using non-native plant material in the absence of seed quality protocols, policies and adequate training for restoration practitioners, thus introducing potentially invasive species and mixing up the ecotypes of widely distributed species.

NASSTEC - The aim

NASSTEC will focus its efforts in the next four years in promoting the use of native seeds for grassland restoration, building the capacity in local companies for large-scale native seed production and lobbying the relevant stakeholders to widely promote the use of native seeds in land restoration and reclamation activities, both in the public and private sector. NASSTEC's ambitious plan aims to create the conditions for a win-win situation, providing ecosystem services, fighting soil erosion, generating income and conserving biodiversity with native seeds

NASSTEC plans to meet these needs by delivering well-trained human resources to support industries and develop new companies, to bridge academia and industry by delivering key information where needed with project manuals, guidelines and toolkits, linking developed markets in US & Australia with Europe, in order to stimulate the largely unexpressed potential of the European market.

Collecting native seeds (MUSE)

Germinating seeds (MUSE)

Harvesting native seeds in Scotland (Scotia Seeds)

Ski slope modelling (MUSE)

Three specific pilot projects for grassland restoration will be carried out in four EU bio-geographical regions (Alpine, Atlantic, Continental and Mediterranean) to demonstrate the potential for grassland restoration, e.g. in ski slopes in the Alps, in major roadwork development in the Scottish highlands and on arable fields in the Mediterranean.

NASSTEC - The Science

NASSTEC plans to interconnect the public and private sector through the establishment of a multidisciplinary European doctoral school with the aim of integrating knowledge in plant ecology, molecular biology, taxonomy, conservation, seed biology, breeding and horticulture. The scientific programme of NASSTEC is articulated in three sub-programmes mimicking the plant reintroduction cycles and the relevant steps necessary for successful habitat restoration.

Sub-programme A covers *in situ* seed sampling and includes the following three PhD projects:

- 1A - based at MUSE - A bio-geographical approach to species selection for the Alpine and Atlantic region.
- 2A - based at Semillas Silvestres - Selection of high-quality grasses for the Mediterranean and Continental bio-region.
- 3A - based at the James Hutton Institute- Methods for seed and seedling phenomics.

Sub-programme B covers seed biology characterisation and includes four PhD projects:

- 4B - based at Pavia University - Bio-geographical aspects of seed dormancy.
- 5B - based at Semillas Silvestres - Propagation protocols for the restoration of grassland habitat in Europe.
- 6B - based at Pavia University - Seed longevity in storage.
- 7B - based at RBG Kew - Life history traits in contrasting environments - intra-species variation in stress tolerance.

Sub-programme C covers production and deployment of seed and includes four PhD projects and 1 post-doc:

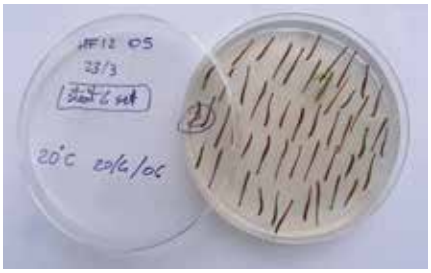
- 8C - based at Scotia Seeds - Improving seed quality in large-scale production.
- 9C - based at RBG Kew - Propagation and seed multiplication protocols for herbaceous flora.
- 10C - based at Syngenta - Seed pre-treatments of native species for optimal establishment, for use in *in situ* restoration.
- 11 C - based at MUSE - Certification of seed quality and provenance.
- 12 C - the post-doc - based at Scotia Seeds - Transfer of NASSTEC knowledge to European seed producers.

NASSTEC - The Training

From an academic point of view, all students are registered in a cross-cutting doctoral programme managed by the University of Pavia and upon successful completion of the training programme they will be awarded PhD qualifications in Earth and Environmental Science. The training programme includes both host-based training and network training, delivering a balanced scheme of exchange visits and secondments, a rich programme of events, news of network achievements and research information.

The network training events include two summer schools providing training respectively in seed collecting in the Asturias in Spain and in seed germination and processing; three specialist workshops that will deliver training

Above right: Native seeds (MUSE)
Above: Scotia Seeds farming native seeds (Scotia Seeds)



Top: Native plants in roadsides in Scotland (Scotia Seeds)
Above: Understanding seed dormancy (MUSE)

in molecular diversity at the James Hutton Institute in Dundee, Scotland; in intellectual property rights, patenting and grant writing at Syngenta, in the Netherlands; in education and outreach at MUSE in Trento, Italy.

The outputs of the project will be presented in the final conference that will be held at RBG Kew in summer 2017 provisionally entitled "Native seeds for environmental mitigation".

The training is completed by three one-month secondments to other network partners, three network annual meetings, various exchange visits and an education and outreach programme.

NASSTEC - The Outreach Programme

It is particularly important to reach out to the wider public and society in general to raise awareness of the importance of native seeds in ensuring appropriate ecosystem services and biodiversity conservation. It is also necessary to gain the support of civil society for the research being carried out by NASSTEC, demonstrating that it is highly relevant for human wellbeing and environmental conservation, and that it meets the request for Responsible Research and Innovation (RRI).

Contact with local schools and community organisations, newsletters, press releases and the use of social media will encourage practical activities based around native seeds such as seed collecting days, seed sowing events and display gardens of native plants. Globally NASSTEC researchers will carry out a selection of the following outreach activities:

- Design inquiry-based science education (IBSE) activities for schools, building on the INQUIRE project, selecting, adapting and using established resources for environmental education in schools and botanic gardens relevant for native seeds and plants, both in formal and informal settings.
- Take part to the local editions of the Researcher's night, usually held in September, contributing with a stand to illustrate the benefits of grassland restoration using native seeds.
- Playing the part of Marie Curie Ambassadors, carrying out a day-visits to local schools, introducing the project and demonstrating its benefit to society, using one of the IBSE activities designed earlier. These visits might include seed collecting days and seed sowing events that will also involve parents of pupils, to raise awareness of the importance of native seeds and of the research being carried out in NASSTEC.
- Taking part in the Fame lab contest to communicate NASSTEC research to the wider public. This contest aims at electing the brightest science communicator in each partner country, eventually reaching the European finals.
- Hosting two-week school teacher placements in each partner lab during the summer break, providing local teachers with the opportunity to understand the research being carried out in partner institutions and raising awareness of the use of native flora among teachers and educators.
- Developing native flower beds displays in 5 key cities of the partner countries, celebrating NASSTEC with native seeds and wildflower grassland displays, showcasing the relevance of native biodiverse grasslands and its garden value.

NASSTEC - The long term impact

NASSTEC ambitiously plans to make a long-term impact on plant conservation in Europe, increasing the competitiveness of human capital and ensuring that it is directed towards the development of a sustainable and dynamic European native seed industry capable of supplying the native seeds required for sustainable grassland restoration. The ultimate goal of NASSTEC is to stimulate a wider use of native seeds in grassland restoration at the European scale.

For further news and updates on the development of the project and its outputs check out www.nasstec.eu

NASSTEC is funded by the European Union under FP7

Costantino Bonomi,
MUSE - Trento Science Museum, Italy

Scotia seeds farming native seeds in mono-specific plots (Scotia Seeds)

Please join Botanic Gardens Conservation International (BGCI) and help us to save plants from extinction

Established in 1987, BGCI links more than 500 botanic gardens and conservation organizations in 115 countries, working together to save Plants for the Planet.

BGCI's INSTITUTION members receive numerous benefits:

- Opportunities for involvement in joint conservation and education projects
- Tools and opportunities to influence global conservation policy and action
- Botanic Garden Management Resource Pack (upon joining)*
- Our twice yearly e-publications:
  - *BGjournal* – an international journal for botanic gardens
  - *Roots* - Environmental Education Review
- A wide range of publications and special reports
- Invitations to BGCI congresses and discounts on registration fees
- BGCI technical support and advisory services

Institution Membership		£ Stlg	US $	€ Euros
A	BGCI Patron Institution	5,500	8,500	7,500
A/B	Principal member	1,900	3,000	2,275
B	Institution member (budget more than US$2,250,000)	1,100	1,650	1,325
C	Institution member (budget US$ 1,500,000 - 2,250,000)	600	990	770
D	Institution member (budget US$ 750,000 - 1,500,000)	440	715	550
E	Institution member (budget US$ 100,000 - 750,000)	240	385	310
F	Institution member (budget below US$100,000)*	110	165	130

INDIVIDUAL members and donors support BGCI's global network for plant conservation, and are connected to it through our publications and events.

BGCI's INDIVIDUAL members receive

- Regular e-publications (these publications are sent as a pdf file via email):
  - *BGjournal* - an international journal for botanic gardens (2 per year)
  - *Roots* - Environmental Education Review (2 per year)
- Invitations to BGCI congresses and discounts on registration fees

Individual Membership		£ Stlg	US $	€ Euros
J	Conservation donor	275	450	375
K	Individual member	80	125	100
M	Friend -available through www.bgci.org/joinin	15	20	18

***Contents of the Botanic Garden Management Resource Pack include:**
Darwin Technical Manual for Botanic Gardens, A Handbook for Botanic Gardens on the Reintroduction of Plants to the Wild, *BGjournal* - an international journal for botanic gardens, *Roots* - Environmental Education Review, *The International Agenda for Botanic Gardens in Conservation, Global Strategy for Plant Conservation, Environmental Education in Botanic Gardens*, additional recent BGCI reports and manuals.

Many of these publications have been translated into Chinese. Please contact us for more details.

❑ **I wish to apply for BGCI's INSTITUTION / INDIVIDUAL membership (circle one).**

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Please clearly print your name (or the name of your institution) in English on all documentation.
An official invoice will be issued outlining the various payment methods when your membership application has been accepted.

Please contact info@bgci.org for further information.

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EUROGARD VII
PARIS

EUROGARD VII, the Seventh European Botanic Gardens Congress

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July 6-10, 2015

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