



The Millennium Seed Bank: building partnerships in arid regions for the conservation of wild species

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The Millennium Seed Bank Project is a large, international conservation project. Most of the project will focus — in collaboration with many dryland countries — on the much-neglected need for conservation of wild species in the (semi-) arid regions of the world. Its principal aim is to help safeguard 24,000 species of dryland plants — 10% of the world's flora — against extinction. A second aim is, equally through *ex-situ* conservation, to secure the future of almost all of the U.K.'s native flowering plants. For the project, a new building has been constructed at Wakehurst Place in Sussex, part of the Royal Botanic Gardens, Kew. After opening in late 2000, it will house the Seed Bank and be a world resource for seed conservation, research and education.

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Introduction and summary

The loss of Earth's biodiversity may be the greatest environmental problem facing humanity. Unlike other such problems, it is irreversible; once a species becomes extinct, it is lost forever. The Convention on Biological Diversity, agreed upon at the United Nations' Earth Summit in 1992, explicitly recognizes the links between biodiversity conservation and sustainable development, and thus stresses the importance of protecting the world's biodiversity. It is in this spirit that the Millennium Seed Bank Project was conceived.

The Millennium Seed Bank Project will build on the knowledge and expertise that the Royal Botanic Gardens, Kew have developed in seed conservation over the last 20 years. The project will involve the construction of the largest seed bank in the world dedicated to conserving wild plants. Although the new Seed Bank building itself will be ready in the middle of the year 2000, the whole project will take a total of 14 years to complete and will involve close partnership and cooperation with many countries around the world.

The Millennium Seed Bank Project will honor the letter and spirit of the 1992 Convention on Biological Diversity, the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and other regional and national laws concerning biodiversity. All seed collecting, storage and distribution will be carried out in accordance with the prior informed consent of the host country under the terms of

a mutually agreed upon and legally binding bilateral agreement. These agreements will ensure fair and equitable sharing of the research results and any benefits arising from the use of the seeds, and will specify the rights and responsibilities of all parties. The two principal aims of the project are to:

- (a) Collect and conserve 10%, or about 24,000 species, of the world's seed-bearing flora, principally from the drylands.
- (b) Collect and conserve seeds of the U.K.'s entire seed-bearing flora.

In addition to these main goals, the project also intends to:

- (a) Encourage plant conservation throughout the world by facilitating access to and transfer of seed conservation technology.
- (b) Carry out research to improve all aspects of seed conservation.
- (c) Make seeds available for research and species reintroduction into the wild.
- (d) Maintain and promote the public interest in plant conservation.
- (e) Provide a world-class facility as the focus for this activity.

Seed conservation

Why do we need to conserve plants?

Plants are the basis of life on Earth. They provide nourishment and other essential living requirements to almost all forms of life, including thousands of mammals and birds, and millions of insects. The tremendous diversity of life on the planet is largely dependent on the diversity of the plant species, which sustain it. If the plants are lost, a huge proportion of the world's other living organisms will disappear too.

The tremendous human cost of such a mass extinction would perhaps be even more daunting. In many parts of the world, people are utterly dependent on plants for almost every aspect of their everyday lives. As well as producing oxygen through photosynthesis, holding the soil together and providing staple food crops, plants are the source of a great many medicines, and form the principal supply of fuel, building materials, clothing, raw materials for local industry and much more. Plants are often lost before we know anything about the benefits they could bring to society. Could the next plant that becomes extinct have provided a potential cure for forms of cancer?

Since the start of agriculture, mankind has stored crop seeds from one year to the next. Because they can develop into whole plants — from the tiniest herb to the tallest of trees — and because they are often produced in abundance, seeds are playing a new and increasingly important role in the conservation and exploitation of wild plants too.

What is a seed bank?

A seed bank is, in effect, a means of keeping living plant seeds in a state of suspended animation. Large quantities of seeds are dried and stored in subzero temperatures, where they can be kept alive for centuries. At any time in the future, the seeds can be germinated to reproduce the plant from which it came.

Structurally, a seed bank consists of a series of large deep-freezers (kept at -20°C) where hundreds of millions of seeds are stored in airtight aluminium and glass containers.

The result of putting seeds into a seed bank is to slow down the rate at which they deteriorate and lose their ability to germinate. Seeds of some plants such as maize (*Zea mays*) and barley (*Hordeum vulgare*) can probably last thousands of years in a cold store

or a seed bank. For some wild plants, centuries is probably a more realistic figure. This is far longer than they could survive in the wild.

Why do we need seed banks?

Pressures on the environment are so great in many areas that it is not always possible to conserve plants in their natural habitats. While we cannot always guarantee the safety of a plant in even the best-protected nature reserve (*in-situ* conservation), plant seeds can be kept safely for hundreds of years in a seed bank. Should a plant become extinct in the wild, with its seeds stored in a seed bank, it will not be lost forever. Seed banks are also very efficient and cost-effective means of conserving plants, because the seed occupies very little space and requires only periodic attention.

Life's strength is in its diversity, and it is as important to conserve genetic diversity within a given species as it is to conserve that of different species. Every individual plant has its own unique characteristics, giving it a competitive edge in a particular habitat or situation. This means that the greater the number and variety of individuals that exist for a given species, the more able that species will be to survive and adapt in a constantly changing environment. Many thousands of seeds can be stored for each species in a seed bank. Each seed represents a potential, genetically unique plant, so the more seeds we store for each species, the more we can guarantee that species' safe future.

The seeds in the Millennium Seed Bank could be used in the future to help restore damaged or destroyed environments — this being of special relevance to dryland regions — or to increase numbers of rare and endangered plants in the wild, thus relieving pressure on the wild populations. They can also be used in scientific research to find new ways for plants to benefit society such as in medicine, agriculture or local industry. Already, 25% of the medicines used in the western world are derived from plants. Yet less than one-fifth of the world's plants have been studied by scientists for the possible benefits they could bring.

The aim of a seed bank is *not* to replace wild populations, but to act as an insurance policy. In a world where the rapid loss of biodiversity is of great concern, the efficiency, effectiveness and ease of seed banking make it an attractive conservation option, especially as a back up to *in-situ* conservation, which is the preferred option. However, even national parks and nature reserves have no real guarantee of long-term security — and neither, therefore, do the plants within them.

Seed conservation at Wakehurst Place

At Wakehurst Place, Kew's research facility and country garden in Sussex, seeds have been stored and studied since 1974. The aim is to understand how seeds work and how we can best store them for future generations. Out of this work, an unrivalled collection of wild plant seeds from all around the world has been built up. In January 2000, it consisted of 12,161 lots, representing a total of 4804 distinct, identified species (within 608 genera and 37 families) and 36 as yet unidentified species in unique genera. This makes up for a grand total of 4840 distinct taxa.

Only so-called orthodox seeds can survive drying to a low moisture content and subsequent storage at subzero temperatures. The majority of species in a temperate flora such as Britain's have such storable orthodox seeds. The other main category of seeds is the so-called recalcitrant seeds, which die when dried. Although no one yet really knows, it is believed that seeds of many tropical rain forest trees are recalcitrant.

One line of research in the laboratories of the Millennium Seed Bank will be to find an easy way of distinguishing between the two seed types and to investigate storage methods for them other than conventional seed banking.

Collecting

At Wakehurst Place, there are staff members who specialize in undertaking seed-collecting expeditions in collaboration with partner organizations. This requires good planning, local knowledge, support and, most importantly, permission to collect.

How are the seeds prepared for storage?

Seeds which arrive back at Wakehurst Place are put into an insulated drying room (at 15°C and 15% relative humidity — as dry an environment as on a typical long-haul flight) so that they gradually dry out. They are cleaned, counted and put into airtight containers, before being placed in the Seed Bank at – 20°C. The seeds are then tested for viability on a regular basis. All information about collections, for example, where and when they were made, and the methods used to germinate them, is entered into a computer database.

How are the seeds from the Seed Bank used?

Eventually, with permission from the country of origin, most of the seed collections make their way into a seed list that is produced to advertise the contents of the Seed Bank. This seed list is available as a printed document or can be requested via e-mail from Seedbank@rbgkew.org.uk by those involved in *bona fide* research. We regret that we are unable to send seeds to private individuals as our stocks and resources are limited.

On request, and after a legally binding agreement covering the non-commercial use of the seeds has been signed, small research seed samples are sent, free of charge, to an increasingly wide range of recipients, such as university departments, agricultural institutes and non-governmental organizations. These include an increasing number in the developing world. They are used for an astonishing variety of purposes, from pure research on improving our understanding of the relationships between different species to growing plants for plant use trials somewhere in the dry tropics. Distribution presently accounts for more than 2000 seed samples every year. An example of its potential impact is a collection from a Mediterranean species of vetch (*Vicia* sp.), which provided a blood-clotting protein, helpful in the detection of rare human blood disorders.

If recipients wish to use any of these seeds for commercial ends, they need the specific permission of the Seed Bank and, in the event of any commercial success, they must agree to its policy of apportioning profits to the seeds' country of origin. Such a policy aims to abide with the spirit of the 1992 Rio Earth Summit and Convention on Biological Diversity and to keep pace with subsequent changes in national and international attitudes and legislation.

The importance of the Seed Bank at Wakehurst Place

So, what has been achieved since the Kew Seed Bank was founded at Wakehurst Place in 1974? Most important, perhaps, is the successful storage of seeds of nearly 5000 species from more than 100 countries — perhaps the most diverse collection anywhere in the world. Some collections of seeds are there purely for conservation, while others are there to be available to the international community so that our knowledge of wild plants and their uses can be improved.

Vast amounts of scientific information about the seeds of wild plants have been generated by the research staff at Wakehurst since the start in 1974. This

information may one day be crucial to revegetating areas with long-gone species or answering questions about the use of a specific plant's chemical compounds, for example.

Seed banking is a relatively new and underexploited tool in combating the loss of global plant diversity. At the very least, it offers an insurance service to other conservation techniques; at the most, it may be the only option available when the last surviving individuals of a species are about to be destroyed.

Conserving the flora of the world's drylands

Targeting: why the drylands?

The world's drylands are home to an immense variety of plant life, including many species that are useful to humans. The drylands support approximately one-fifth of the world's population (far more than the tropical rain forests), as well as 50% of the world's livestock, and provide forage for both domestic and wildlife. Although less publicized than the rain forests, drylands are among the most threatened environments on Earth, with huge areas being lost to deserts every year. The natural vegetation is the source of livelihood for many people in these regions, and its loss can lead — and has — to famine.

The Millennium Seed Bank Project has identified partners in many dryland countries to work jointly on the conservation of their floras. Eight major countries with rich, diverse floras are targeted: Australia, India, Kenya, Madagascar, Mexico, Morocco, South Africa, and the U.S. In addition, many other countries are involved, such as Botswana, Burkina Faso, Chile, Egypt, Ethiopia, Jordan, Lebanon, Mali, Namibia, Saudi Arabia, Tunisia, Yemen, and Zambia.

Desertification is widely recognized as the main threat to drylands. The process is partly climatic in origin, but is certainly exacerbated by population pressures. Moreover, it is a problem in many of poorest countries of the world. For seed conservation purposes, however, it makes for relatively easy collecting logistics. Moreover, drylands harbor a high proportion of species, producing seeds that are likely to tolerate desiccation, thus creating the option for safeguarding through *ex-situ* conservation in seed banks. It must be noted that this is in marked contrast with the rainforests, where many (perhaps the great majority) of the species produce seed that cannot tolerate seed-bank storage conditions, and where, therefore, this backup function of seed banks does not exist.

We intend, through establishing partnerships in dryland countries that the partners take priority, and that a balance between species of local and global conservation concern, as well as a balance between species of short- and long-term value to the rural poor is maintained.

By the year 2010, the project intends to have collected and conserved 10% of the world's flora — approximately 24,000 species — concentrating on the drier areas of the tropics and subtropics. The huge task of collecting the seed will be based on international collaboration and information sharing.

Access to the seeds and benefits shared

The Millennium Seed Bank will be a world resource, and as such, the seeds, where possible, will be made available to researchers, conservationists and scientific institutions throughout the world free of charge, but under the terms and conditions as guided by the 1992 Convention on Biological Diversity. Fair and equitable sharing of any benefits arising out of the use of the seeds will be guaranteed. Next to benefits from the use of the

seeds, other shared benefits on offer through the Millennium Seed Bank may include:

- (a) Facilities for long term storage of duplicate material.
- (b) Processing and viability testing of stored material.
- (c) Taxonomic identification and verification of material.
- (d) Acknowledgement of Partner as the source of material for published research data, derived from material.
- (e) Joint authorship of publications as appropriate.
- (f) Financial support of seed-collecting activities.
- (g) Provision of technical expertise for development of in-country seed-conservation facilities.
- (h) Training in seed handling, storage and research techniques.
- (i) Access to formal training courses at the Royal Botanic Gardens, Kew.

Of all the seeds that are collected throughout the duration of the program, it is also intended that a substantial proportion be kept in the country where the seed originated.

Research, training and technology transfer

One of the most important aspects of the Millennium Seed Bank Project will be to share expertise in seed conservation with collaborating countries. Visiting scientists, working on their own native flora alongside Kew staff, will carry out some of the seed processing and research at the Millennium Seed Bank. Where relevant, the project aims to assist other countries to set up their own seed banks.

Researchers will strive for a better understanding of the underlying processes of seed traits such as germination and storability, thus improving the efficiency of seed banking methods. In partnership with our overseas collaborators, low-technology solutions to seed conservation problems will also be sought, and technology transfer and capacity building will be achieved through formal and informal training.

The new Wellcome Trust Millennium Building will include on-site accommodation for visiting scientists in the form of 14 bedrooms. Training will be available at all levels of expertise, from technician up to post-doctoral and for various lengths of time, from one month to several years. Indeed, approximately half of the research space in the building will be available for overseas collaborators.

Public awareness and information

Informing the public of the importance of conserving the Earth's plant life is essential and will be a crucial part of the project. About 300,000 people visit Wakehurst Place every year, and many of these are expected to come to learn about the Millennium Seed Bank Project and see the new facility.

There will be a state-of-the-art exhibition about seeds and plant life, which is intended to include a screen-based virtual tour of the Seed Bank's vault. Large windows into the seed preparation areas will make it possible for visitors to observe seed conservation in action and fully appreciate its importance. Outside the building, various habitats for the U.K.'s flora will be represented in raised beds.

Funding

The project is expected to cost approximately £80 million. Of this, The Millennium Commission has awarded a grant of up to £30 million to the project, and Kew is

contributing a further £8 million over 14 years. The Wellcome Trust has provided a grant of £9.2 million, and a substantial amount has been raised by the Millennium Seed Bank Appeal from companies and the public, with Orange Plc as its premier sponsor.

Additional funding to support the overseas collecting program, and for technology transfer and training will be sought from international donor agencies and commercial sponsors.