crop wild relatives

A Global Rescue

SAFEGUARDING THE WORLD'S CROP WILD RELATIVES

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Introducing the Wild

Humans have been manipulating plants since farming began more than 10,000 years ago. That has led to the high yielding and nutritious crops that feed us today. But the process has also narrowed their genetic diversity, and that makes them more susceptible to pests, diseases and extreme climatic conditions.

Now, as agriculture faces new and ever harsher challenges due to the changing climate, we urgently need to re-equip crops with the ability to cope with drought, flooding and salinity. The key to developing these more resilient crops is to look beyond the diversity that plant breeders have traditionally used in their crop improvement programs, and tap into the genetic diversity still found in nature.

We need to turn to the wild.

A tiny, scraggly, easily overlooked plant could provide just the genetic diversity a crop breeder needs. These unsung heroes are crop wild relatives (CWR). To survive in the wild, these untamed cousins of our pampered crops rely on traits that allow them to survive under more challenging conditions than their domesticated counterparts. For plant breeders, CWR present a still largely untapped source of genetic diversity that can help them transform agriculture, at a time when farmers need to produce more with less, whilst facing more erratic climatic conditions.

To develop new varieties, breeders need access to new genetic material. Increasingly, they are looking to CWR to find it. But a global gap analysis made it clear that many CWR were largely missing from genebanks – the collections of seeds that national and international institutes maintain under special conditions which ensure their long-term survival and availability. CWR were thus not easily available for use by breeders and researchers. Making matters worse, CWR are rapidly disappearing from their natural habitats, due to deforestation, urbanization, intensive grazing, the spread of intensive agriculture and other pressures. Once CWR are gone, we lose their genetic diversity forever and the wealth of possibilities that it offers to plant breeders.

> If we are to feed a growing population despite climate change, we need to make our food crops more resilient. Crop wild relatives can help breeders "climate-proof" agriculture.
>
> **Marie Haga,** Executive Director, Crop Trust

To ensure food security in a changing world, we urgently need to conserve CWR.

In 2013, the Crop Trust entered into a collaboration with the Millennium Seed Bank (MSB) of the Royal Botanic Gardens, Kew and national partners in 25 countries around the world, to find, collect and conserve the endangered wild relatives of 28 important food and forage crops. This ambitious effort is part of a 10-year multi-stage project, funded by the Government of Norway, aiming at "Adapting Agriculture to Climate Change." We call it the CWR Project for short.

The CWR Project mobilized experts who traveled to the remote corners of their countries with collecting kits in hand, searching for hundreds of CWR, which were underrepresented or completely missing from genebank collections. The challenges these collectors faced were many and varied, but their efforts will play a key role in reaching food security.

Now that the six-year collecting phase of the project has come to an end, we look back and celebrate what has been achieved.

In the following pages, we share with you what we think made this effort worth every one of the nearly 3,000 days our partners spent out in the field.

Collecting at a Glance

25

national partners
on four continents

Wild relatives of

28 important crops collected

4,644 seed samples collected ...

... of 371 different species or subspecies

Six Years

of collecting
2013–2018

Led by the Crop Trust with Kew's MSB with support from the Government of Norway

MSB
Millennium Seed Bank

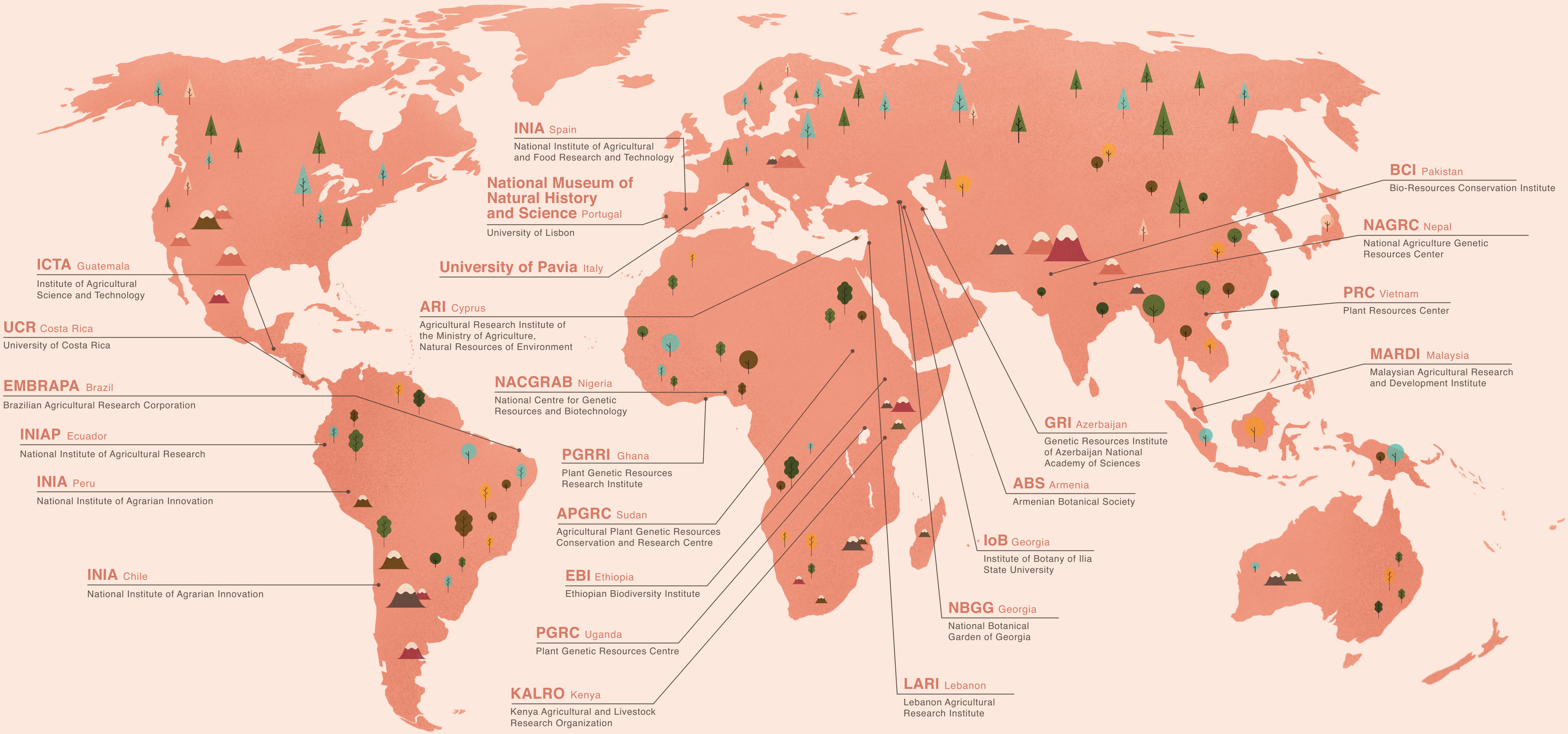
To date, Kew's MSB has received 3,477 samples from national collecting partners, for long-term storage and safety duplication

Passport data for **3,477** samples publicly available through the online platform Genesys

A Global Collecting Effort

In this coordinated global effort, partners of the CWR Project ventured far and wide in 25 countries to search for some of the most important crop wild relatives. The map on the next page shows the partners involved in this effort.

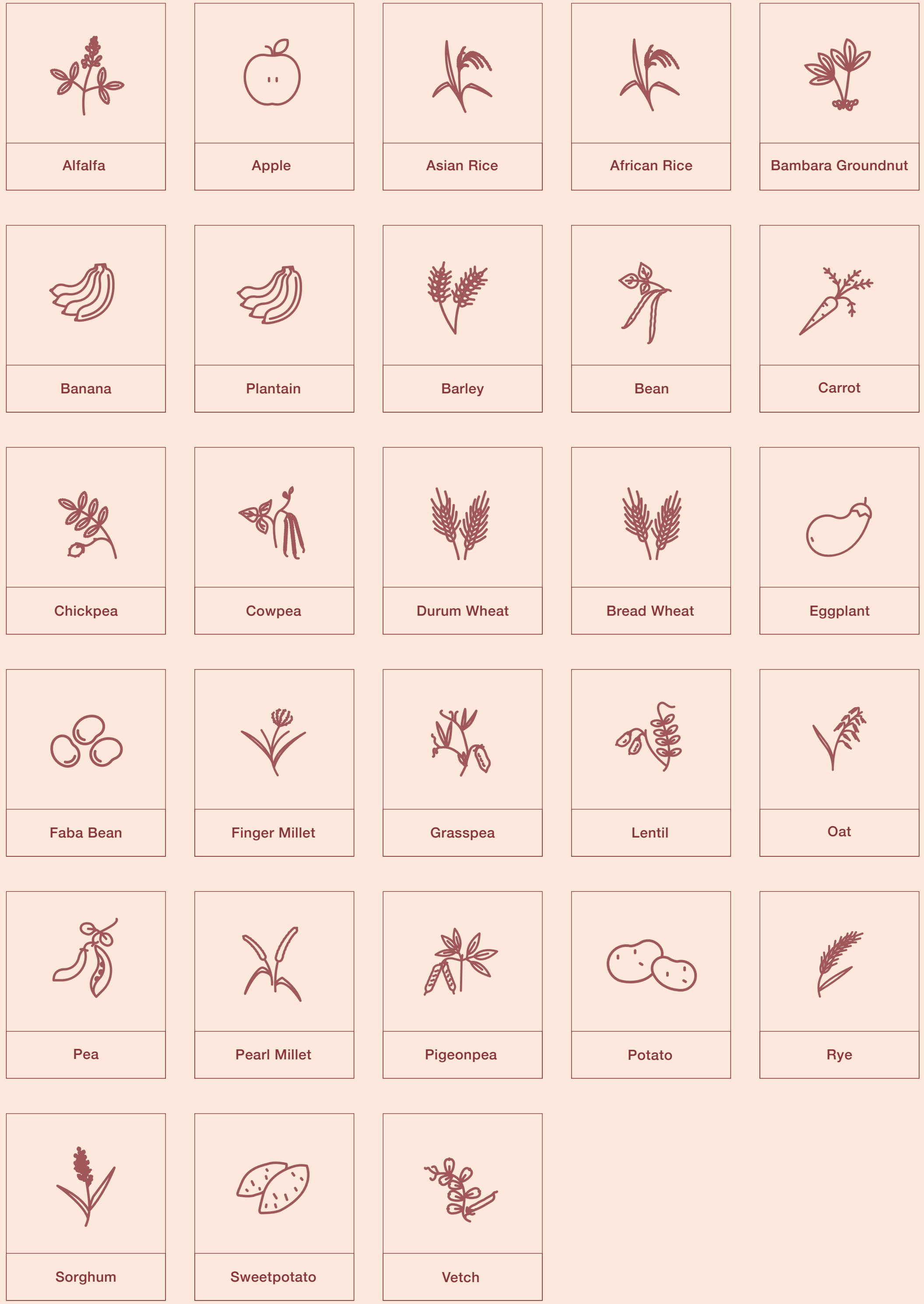
A GLOBAL COLLECTING EFFORT

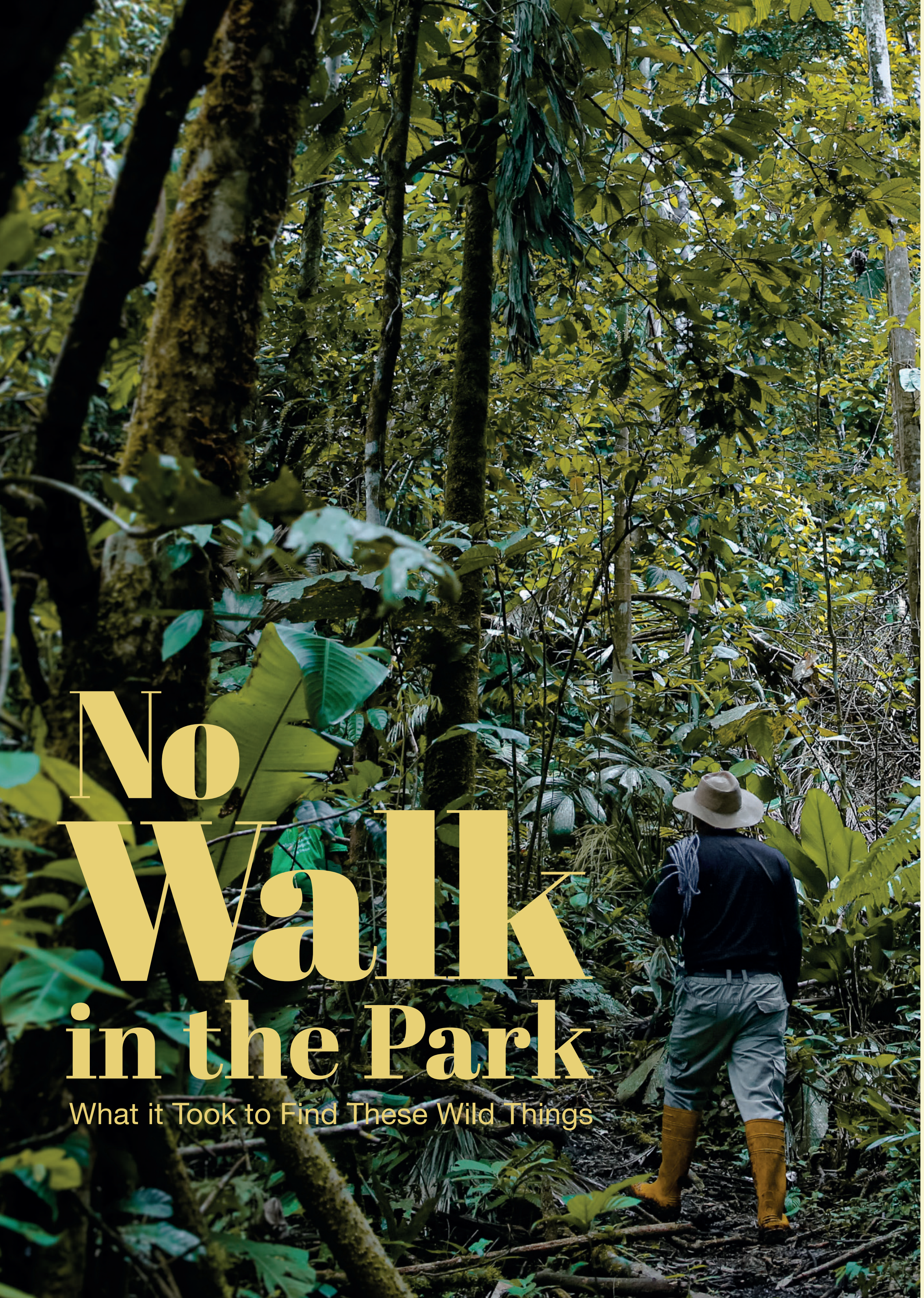


Crop Genepools Collected

The wild relatives of a crop cluster together in what is called a "genepool". Although they might be different species, they are still closely enough related to crops to allow the exchange of genetic traits; that means they can be used in crop improvement programs.

In the CWR Project, national teams collected the wild relatives belonging to the genepools of 28 crops. All of these crops are included in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture (the Plant Treaty), which recognizes their importance for food security and global interdependence.





No Walk in the Park

What it Took to Find These Wild Things

Scientists have long been traveling around the world to collect plants, first to grow in gardens and more recently to conserve them in genebanks.

They have always faced similar challenges: lack of information, bad weather, washed out roads, running out of money and simple bad luck. Our partners had to prepare for everything – and hope for a bit of luck – when searching for CWR. These are a few of the things successful collectors need.

Careful planning

Seed collectors must carefully plan where to look and exactly what to look for. Some plants are extremely rare and previous records, such as herbarium specimens, may simply not be available, or incorrectly identified.

Adventurous spirit

To reach remote locations, collectors traveled by foot, horse, jeep and boat. Sometimes, as our partners from the National Agriculture Genetic Resources Center (NAGRC) demonstrated, they even rode elephants in search of CWR. Our adventurous collectors couldn't go everywhere though – some collection sites were no-go zones due to security reasons.

Perseverance

The trips were perilous and physically demanding – imagine marshlands full of mosquitoes, burning sun on high-altitude plateaus and frigid rain in cloud forests. You need a certain kind of stubbornness to cope with all this – all the while conscientiously collecting seeds and data.

> Collecting needs to happen at just the right moment – close is often not good enough.

Hannes Dempewolf, Senior Scientist at the Crop Trust

Perfect timing

The window for collecting good seeds is narrow: too early, and the seeds are immature and useless, too late and they're gone with the wind. If collectors missed that window, they had to visit the same site again at a later date or even wait for the following year's season.

Patience

Days can go by without finding the plants you're looking for. Sometimes, several trips to the same location were needed, with teams combing through vast areas without success. For example, it took four attempts and four locations for our collecting partners in Ecuador to find the wild potato they were seeking.

Serendipity

Nicola Ardenghi of the University of Pavia in Italy spotted *Lathyrus tuberosus* by chance while looking out of a train window. His team had almost given up hope of finding it when he briefly caught sight of a large patch of the unmistakable red flowers. He didn't immediately jump out of the speeding train. But almost.

> I'm afraid that it's likely that we will be the last people to ever collect and conserve this specific population.

David Kikodze, Deputy Director of the Institute of Botany at Ilia State University, Georgia, searching for *Medicago marina*, a wild relative of alfalfa.

NO WALK IN THE PARK

Facing the reality ...

Extreme weather conditions were a constant concern – floods where it used to be dry, and drought where plants were adapted to high rainfall. In 2014, the Cyprus team started its collecting efforts while the country suffered one of the worst droughts in its history. In 2017, many roads were made impassable by heavy rain in Peru. None of this deterred the seed collectors.

Equipped with the best information available on previous sightings of their target species, including latitude, longitude and estimates of the time the plants would flower and bear fruits, collectors designed routes that would take them to as many potential collecting sites as possible in the time available. If problems came up on the way, they solved them, or went around them, or waited until they passed. Often, however, they came back empty-handed. Though not for want of trying.

... of climate change

In several cases, collectors did not find the plants where they expected them to grow, and considered moving on, but then pushed on into areas not previously known as the plants' habitat, just in case. In southern Brazil, for example, some wild potatoes have moved into cooler regions and up into the mountains.

In Pakistan, collectors found a wild relative of chickpea, *Cicer macracanthum*, 500 meters higher up the mountain than it was ever sighted before. Almost every national collecting partner has a tale to tell of not finding plant populations in previously confirmed sites. We might already be seeing the consequence of a changing climate.

Filling the Gaps

After six years of searching around the world, our partners packed up their collecting gear at the end of 2018.

Taken together, they spent 2,973 days out in the field. If this had been a single person, rather than an international collaborative effort, she would have been collecting **every single day** for more than eight years, seed bag in hand, eyes pinned to the ground.

During this effort, 4,644 unique seed samples were collected. As 4,000 was the target agreed upon prior to embarking on the collecting program, this exceeds expectations and hopes. Still, some CWR proved to be extremely rare or just could not be found. Luckily, what was not found in one country was sometimes found in another – highlighting one of the the benefits of a coordinated, global effort.

These 4,600+ samples cover 371 different species and subspecies. Many species were collected multiple times – on different continents, in different countries, and in different regions within a country. This was all part of the plan: capturing and conserving as much diversity as possible both within and among species. For example, 16 national partners set out to collect the wild relatives of potato and eggplant. Together, they managed to secure 919 samples, from South America, Central America, Africa and Asia. For the genus *Vicia*, which includes faba bean and common vetch, 13 countries in Europe, Africa and Asia managed to secure 413 seed samples. 356 samples of wild alfalfa (*Medicago*) were collected from 10 countries; 347 samples of wild barley (*Hordeum*) from 11 countries; and 332 samples of wild rice (*Oryza*) in 12 countries. Truly an international effort.

In the hierarchy of plant taxonomy, a **genus** contains different species. For example, the genus *Solanum* contains the **species** *Solanum tuberosum*, the potato, and the species *Solanum melongena*, the eggplant.

At the start of the CWR Project, the gaps in existing collections were analyzed and highlighted.

For some CWR, no samples at all were conserved in any genebank. Here are some examples:

Avena eriantha, a wild relative of oat that is known to be resistant to powdery mildew, a common and devastating disease. Thanks to the CWR Project, collectors in Armenia, Azerbaijan, Cyprus and Lebanon managed to secure 10 samples, making the unique traits of this wild oat available to the international breeding community.

Solanum ayacuchense, Solanum olmosense and ***Solanum multiflorum***, three wild potato species that were previously missing from any collection were found in Ecuador and Peru.

Vigna subterranea var. spontanea had previously been missing from genebanks. Our Nigerian partners secured 17 samples of this wild relative of the Bambara groundnut.

The gap analysis concluded that some CWR may be found in genebanks but only in very limited numbers. For example, only a few samples of a subspecies of wild carrot that grows under salty conditions were being conserved. Under the CWR Project, four more populations were tracked down and collected in Portugal.

2,973: total number of days spent in the field searching for CWR
4,644 total samples collected
371 different species
Top five genera collected: *Solanum, Vicia, Medicago, Hordeum, Oryza*

Searching Everywhere

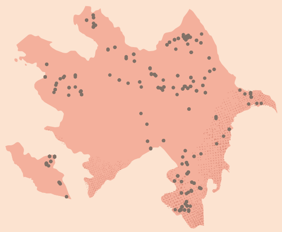
National partners had to cover a lot of ground. In many cases, different species grew in very different natural habitats – the wild potato high up in the mountain, the wild finger millet in low grasslands.

But even when focusing on collecting a single species, it was important that collectors went the extra mile.

The same plant species growing in different habitats might have different adaptations, further boosting the genetic diversity the collectors could capture to take home and conserve for the long-term in their genebanks.

We are looking to capture as much diversity as possible; this means collecting the same plant multiple times. **It sounds like a waste of time, but populations separated by even a few kilometers may be genetically quite different.**

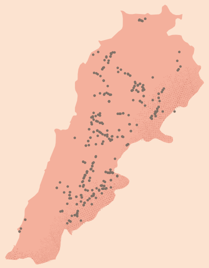
Luigi Guarino, Director of Science, Crop Trust



Azerbaijan

Most national partners had a rough idea of where their target species grew. Perhaps even more importantly though, they knew where previous collectors had not ventured to collect CWR in the past. In Azerbaijan, collectors spent a total of 164 days from 2015 to 2017 out in the field and systematically visited targeted areas throughout the country. They searched grasslands, forests, meadows and steppes. All collecting trips started from Baku in the east, going as far as Kusar in the north, Ganja in the west, Lankaran in the south and also the Nakhchivan region in the far west.

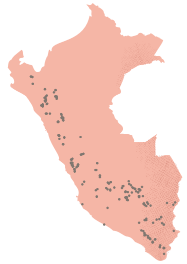
The Azerbaijan team collected **363 samples of 59 species**.



Lebanon

Our collecting partners in Lebanon focused on members of the grass and pea families. According to data assembled and analyzed prior to the collecting trips, in Lebanon the CWR in question normally mature at the end of May and beginning of June. Conditions were extremely dry during the first collecting trips in 2016 and the seeds of many plants had already dispersed when collectors arrived at the designated place and time. In response, collecting missions in the following year started in March. Our partners collected the CWR in woodlands, orchards and fallow lands, riversides and seashores, as well as rocky mountainous terrain. They spent 209 days out in the field.

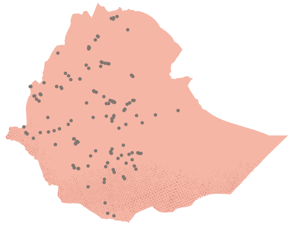
The Lebanese team collected **413 samples of 66 species.**



Peru

The team in Peru undertook 18 collecting trips from 2017 to 2018. They covered the length of the country from Tacna and Puno in the South, up to the most northern areas around Piura, searching in humid and dry forest habitats, deserts, shrublands and rainy tundra. In total, our Peruvian partners spent 141 days out in the field.

The Peruvian team collected **322 samples of 37 species.**



Ethiopia

In Ethiopia, collecting missions focused on the western and central regions. Our collecting partners knew that collecting in the Benishangul-Gumuz region in the west was particularly urgent, as the building of a hydroelectric dam was severely affecting wild habitats. In general, pockets of vegetation surrounded by farmland proved to be a good place for collecting CWR. From 2016 to 2018, our partners spent 86 days out in the field.

The Ethiopian team collected **145 samples of 27 species.**

Peru's Wild Potatoes

Potatoes are the world's fourth most important food crop, after maize, wheat and rice. However, the modern potato has limited genetic diversity and many varieties are susceptible to diseases.

What's more, tubers do not form if night temperatures are too warm, and in recent years, potato farmers have had to move further up mountains and escape to cooler areas. Meanwhile, some of the crop's wild cousins happily grow from lowlands to 4,500 meters of altitude, surviving cold winters and dry, hot summers. Still, to date, only a few wild potatoes have been used in breeding programs to get this extra diversity into the crop where it might do some good for farmers.

For me, these were marvellous trips. We found two wild potatoes that had never been collected before.

This is very satisfying to me personally and a tremendous success for the whole potato world.

Alberto Salas, an agronomist at CIP considered to be the "godfather" of wild potatoes. Despite being in his mid-seventies, he led some of the CWR collecting efforts and takes great pride in their achievement.

It comes as a surprise to many people that the origins of the potato, *Solanum tuberosum* lie high in the Andes. Farmers have been selecting the best tubers there for more than 7,000 years. Eventually, the potato spread from the Andes to Europe, to then conquer much of the rest of the world. But even before Andean farmers started domesticating the potato, its wild relatives had spread across the Americas. More than 150 wild potato species are known, from Texas to Tierra del Fuego, with more than 80 growing in Peru.

A team of determined collectors from Peru's National Institute of Agrarian Innovation (INIA) worked in collaboration with the International Potato Center (CIP), also based in Peru, to collect the most threatened wild relatives of potato in that country. The collecting teams got all the necessary paperwork and permits, received a custom-made collecting guide from our friends at Kew's MSB and meticulously prepared expeditions to various parts of the country. In two years, the joint INIA-CIP team spent 141 days in the field.

During a visit to the northern and central parts of Peru in 2017, the collectors confronted a major challenge when a particularly bad El Niño caused heavy rains, landslides and road closures. They later experienced the opposite on the coast, where the plants they were looking for had not fully developed due to lack of rain. The team responded immediately by altering their itinerary and re-allocating project resources to other areas. The following year, things were better, and the team was able to search for every wild potato on their target list.

The collectors in Peru succeeded in collecting 322 samples, belonging to an impressive 37 different species.

When we analyzed what was available in genebanks worldwide it became clear that almost half of the wild relatives of potatoes were in urgent need of collection, as genebanks held only very few samples of each species – and in many cases none at all. But we were able to figure out the best places to go to fix this.

Nora Castañeda-Álvarez, lead researcher in the global study on CWR conservation priorities

One of those was *Solanum gracilifrons*, which had been classified as critically endangered in its native habitat. Prior to this collecting effort, only one sample was conserved in CIP's international genebank. For the Peruvian collectors, and indeed potato researchers worldwide, finding and conserving more samples was a high priority. They did finally find one population in the wild. But only one. Though they searched for more, none were to be found. But collecting one sample is still a success. Even more satisfying was spotting *Solanum ayacuchense* and *Solanum multiflorum*, wild potato species that had been completely missing from any collection worldwide.

The team had to collect many samples as tubers when plants did not carry mature seeds. As part of the ongoing conservation process, these samples will now be grown out in collaboration with CIP, to secure enough seeds for conservation and distribution.

Despite their best efforts, the collectors could not find some species. The populations might have been lost, or – fingers crossed – just moved to other areas, waiting to be found by future collectors. The work of the collector is never done.

Collecting Around the World

Wild diversity does not recognize geopolitical boundaries.

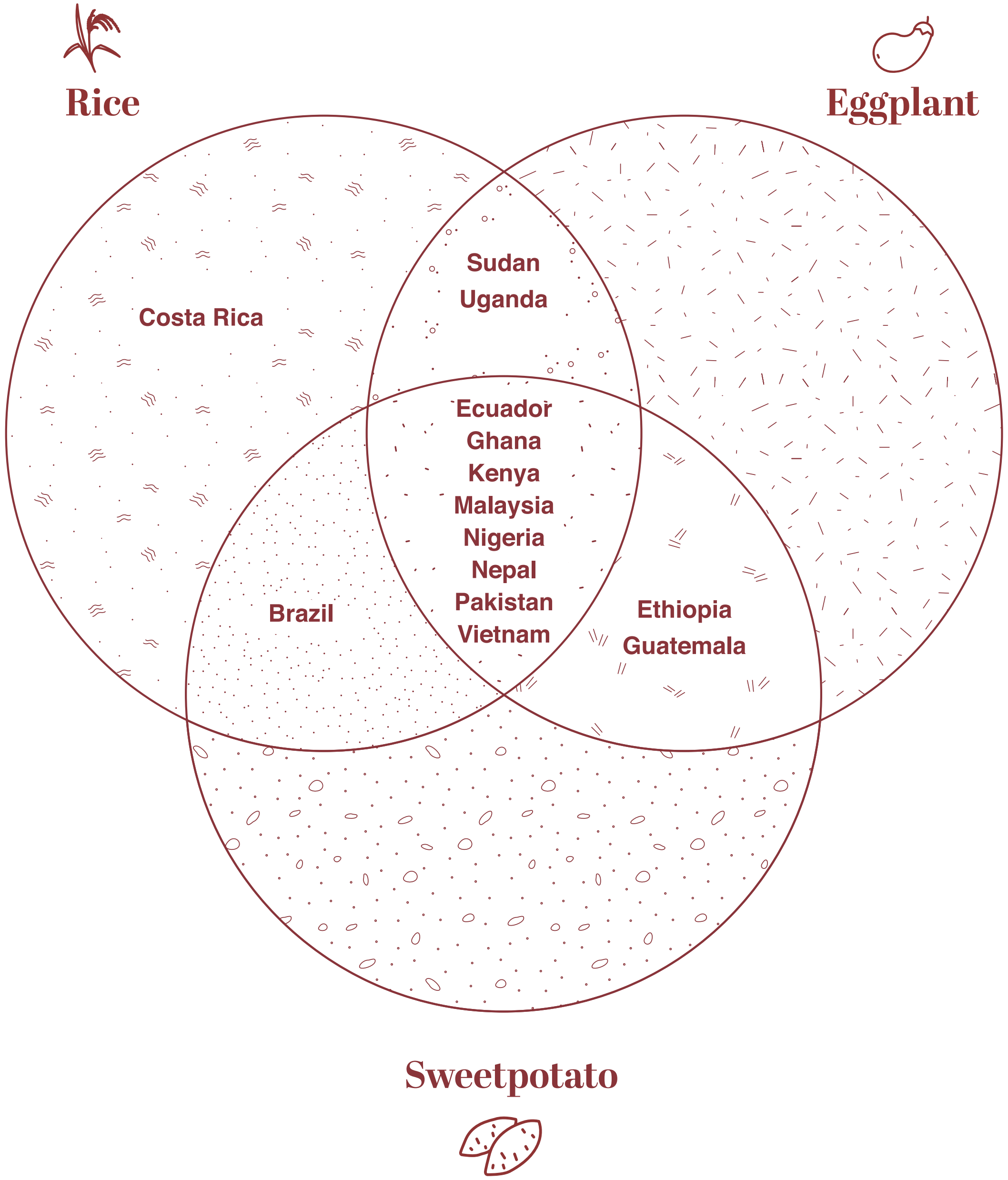
A rice wild relative found in Brazil is different from one found in Pakistan. And those two are different from a wild rice relative found in Vietnam, or in Nepal. Yet, they are all family. And they all have potentially useful traits that we as a global community might need to feed a growing world.

The CWR collecting initiative was truly a global effort — not simply because it supported national partners around the world but because the work carried out by these partners complemented each other. More importantly, the collecting was done to ensure food security for all of us. This is clearly exemplified in the worldwide search for the wild relatives of rice, sweetpotato and eggplant.

We live in an interdependent world. No single country or region harbors all of the diversity that we need. A wild relative of one of these crops, in the Americas, Africa or Asia, could be the source of say, pest resistance, which can benefit all of us in the future.

Chris Cockel, CWR Project Coordinator at Kew's MSB.

Here we highlight the collecting efforts undertaken for three crops around the world and how this global approach focusing on interdependence is bigger than the sum of its parts.



Rice

Two rice species are commonly cultivated: Asian rice (*Oryza sativa*), grown worldwide, and African rice (*Oryza glaberrima*), grown primarily in West Africa. Collectors in 12 countries searched for *Oryza* wild species.

Teams in Brazil, Ecuador and Costa Rica collected *Oryza grandiglumis,* a wild rice endemic to tropical America. It's a tall, perennial rice, which is interesting to scientists because it tolerates flooding and is high yielding.

Our partners also collected *Oryza longistaminata*, a perennial African wild rice. It holds traits that make it resistant to stem borers, which are insects that can chew up and destroy entire rice plants.

In Pakistan, one of the biggest successes was finding *Oryza coarctata*, an Asian rice that can cope with high salinity.

The collecting teams in Nepal collected *Oryza meyeriana*. This potentially important wild relative of Asian rice is resistant to bacterial blight, one of the most serious diseases in rice cultivation.

Collecting countries: Brazil, Costa Rica, Ecuador, Ghana, Kenya, Malaysia, Nepal, Nigeria, Pakistan, Sudan, Uganda and Vietnam

Sweetpotato

Eleven partners in the Americas, Africa and Asia traveled to fields and forests to track down sweetpotato's wild relatives.

One of their targets was *Ipomoea cairica*, which they secured in Kenya, Ethiopia, Malaysia, Pakistan and Nepal. It's a wild cousin of sweetpotato that copes well with several stresses, such as high salinity and insect attacks. It grows in a range of habitats, from almost sea level up to more than 2,000 meters of altitude.

Our partners in Ecuador, Guatemala and Brazil all looked for, and found, *Ipomoea tiliacea*. It copes well with heat and high rainfall.

Two wild sweetpotatoes could, however, only be found in Brazil. *Ipomoea cyanchifolia*, is known to tolerate drought, high rainfall and sandy soils. The second, *Ipomoea grandifolia*, copes well with cold and varying temperatures and grows well on sandy and clay soils.

Collecting countries: Brazil, Ecuador, Ethiopia, Ghana, Guatemala, Kenya, Malaysia, Nepal, Nigeria, Pakistan and Vietnam

We never thought we would be able to collect *Oryza coarctata*. In the past, we had worked in the northern regions of Pakistan, where the species is found, but we were not able to collect it.

Thanks to the CWR Project, we succeeded for the first time and hope there will be many more successes like this to come.

Sadar Sidiqui, Genebank Curator, Bio-Resources Conservation Institute in Pakistan

Eggplant

A global study on CWR and their conservation status found that more than 95 percent of all surveyed eggplant wild cousins needed to be collected urgently. Areas of eggplant diversity are particularly found in Africa and Asia. Some wild species span continents.

National partners in 12 countries succeeded in conserving wild plants underrepresented or not found in genebanks before.

Teams in Ecuador and Guatemala, as well as on the other side of the world, in Nepal, collected *Solanum torvum*, a wild relative known for its resistance to biotic stresses (such as bacterial and fungal wilts, and nematodes).

Our partners in Kenya were particularly fortunate. They found not one, not two, not three, but FOUR wild relatives of eggplant that had previously not been conserved in any genebank worldwide.

National partners collected *Solanum agnewiorum, Solanum setaceum, Solanum malindiense* and *Solanum usambarense* from coastal bushes and dunes, open grassland and hidden away in forests. Little is known about these eggplant wild relatives and the genetic traits they might hold. Finding and conserving them makes them available to the global scientific eggplant community for the first time.

Collecting countries: Ecuador, Ethiopia, Ghana, Guatemala, Kenya, Malaysia, Nepal, Nigeria, Pakistan, Sudan, Uganda and Vietnam

Crops in the Spotlight

Staple crops like wheat, maize and rice satisfy most of our daily need for energy, but people around the globe cut, cook, mash and consume a multitude of other plants. Here we highlight a few of the crops whose wild relatives were collected under this project.

Bananas and plantains

The bananas we eat today have a narrow genetic base, and a disease outbreak could wipe out monocultures around the world. It's happened before. The Panama disease was a single fungus that in the 1940s destroyed plantations in entire countries. Banana's wild cousins may hold the key as they could have genetic diversity that the domesticated crop lacks. When our partners went to collect these plants, they realized that they were racing against time – and primates too, who would often eat the wild bananas before they could be collected. Once found in abundance along the roadsides of Southeast Asia, today wild bananas are often only found deep in the rainforest and are quickly disappearing due to deforestation and rapid urbanization.

Collecting countries: Kenya, Malaysia, Nepal and Vietnam
Results: 131 samples of nine different species

Bambara groundnut

Bambara groundnut is cultivated by subsistence farmers primarily in West Africa. It tolerates high temperatures and drought, fixes nitrogen and grows well on poor soils. It's considered a "complete food" that people can rely on for their nutritional needs, but it hasn't received sufficient scientific attention to really take off. According to the gap analysis, there were no samples of its wild relative (*Vigna subterranea* var. *spontanea*) in any genebank, so it was given a high priority.

Collecting country: Nigeria
Results: 17 samples

Barley

The wild relatives of barley are found in temperate regions and many have developed tolerances to various types of stress. *Hordeum marinum* and *Hordeum brevisubulatum*, for example, cope extremely well with saline soils. Despite its potential value, however, *H. brevisubulatum* was poorly represented in genebanks. Although it is a common sight in grasslands in the Caucasus, our collecting partners in Armenia struggled to collect its seeds. Farmers cut their fields before the seeds are ready for collecting.

Collecting countries: Armenia, Azerbaijan, Chile, Cyprus, Spain, Georgia, Guatemala, Italy, Lebanon, Pakistan and Portugal
Results: 347 samples of 21 different species, including 13 samples of *H. brevisubulatum*

Common bean

The common bean comes in many colors and patterns – and so do its wild relatives. Whilst breeders have had huge success in increasing bean yield and nutritional value, exploiting its wild relatives for stress tolerance traits has received little attention. The efforts of collectors may change that. *Phaseolus microcarpus*, for example, a tiny wild relative of bean that grows on rocky outcrops, was identified and collected for the first time in Costa Rica. Furthermore, it was also found very close to the beach, raising the hope that this population might be salt tolerant.

Collecting countries: Costa Rica, Ecuador, El Salvador and Guatemala
Results: 102 samples of 12 species

Many Players, One Goal

Our 25 national collecting partners played an essential part in achieving the overall goal of the CWR Project. As examples, here we highlight the work of four of our partners to illustrate differences and the multi-faceted realities of collecting missions.

Brazil

The Brazilian Agricultural Research Corporation (EMBRAPA) was the only partner institution that structured its collecting missions by crop, that is, four separate teams went to the areas where their respective target plants were expected to grow. They had to do that because the wild relatives of rice, sweetpotato, potato and finger millet live in quite distinct regions of the country, for the most part. The sweetpotato team observed a severe decline in the abundance of their species in the diversity hotspot of the Atlantic forest compared to past observations.

Our partners in Brazil collected **175 samples of 13 species.**

Chile

Split into three separate teams, our partners from the National Institute of Agrarian Innovation (INIA) explored the Juan Fernandez Islands, the Magallanes Region in the extreme south, and the region north of Magallanes. Severe floods during the years of collecting altered the habitat and occurrence of many target species. In the Maule region, a massive fire destroyed 4,000 hectares, including the habitat of a wild barley, *Hordeum chilense*. Determined collectors managed to collect one sample of this species, which otherwise might have vanished from the area. Our INIA partners also collected wild alfalfa, finger millet and potato.

Our partners in Chile collected **154 samples of 15 species.**

Nigeria

Collectors from the National Centre for Genetic Resources and Biotechnology (NACGRAB) faced extreme challenges in the first two years of their collecting effort. The northeast region was inaccessible due to the Boko Haram insurgency, and in 2016, heavy floods in the south and southwest made many collecting sites inaccessible. In 2017, however, they were able to collect in all six regional target zones. They were the only country to collect the wild relative of the Bambara groundnut, the third most important grain legume in semi-arid Africa. NACGRAB also collected wild relatives of finger millet, pearl millet, eggplant, sorghum, sweetpotato, rice and cowpea.

Our partners in Nigeria collected **205 samples of 20 different species.**

Pakistan

The Bio-Resources Conservation Institute (BCI) collected species related to 18 target crops: alfalfa, apple, barley, carrot, chickpea, eggplant, finger millet, grasspea, lentil, oat, pearl millet, pigeonpea, rice, rye, sweetpotato, sorghum, vetch and wheat. This was the highest number of crop genepools collected in any one country. Considering the importance of Pakistan as a CWR hotspot, the collecting team there decided to do something about the limited understanding of these plants and their importance in the country. The country's first national seminar on CWR attracted over 200 attendees, including conservationists, botanists, breeders, and policymakers.

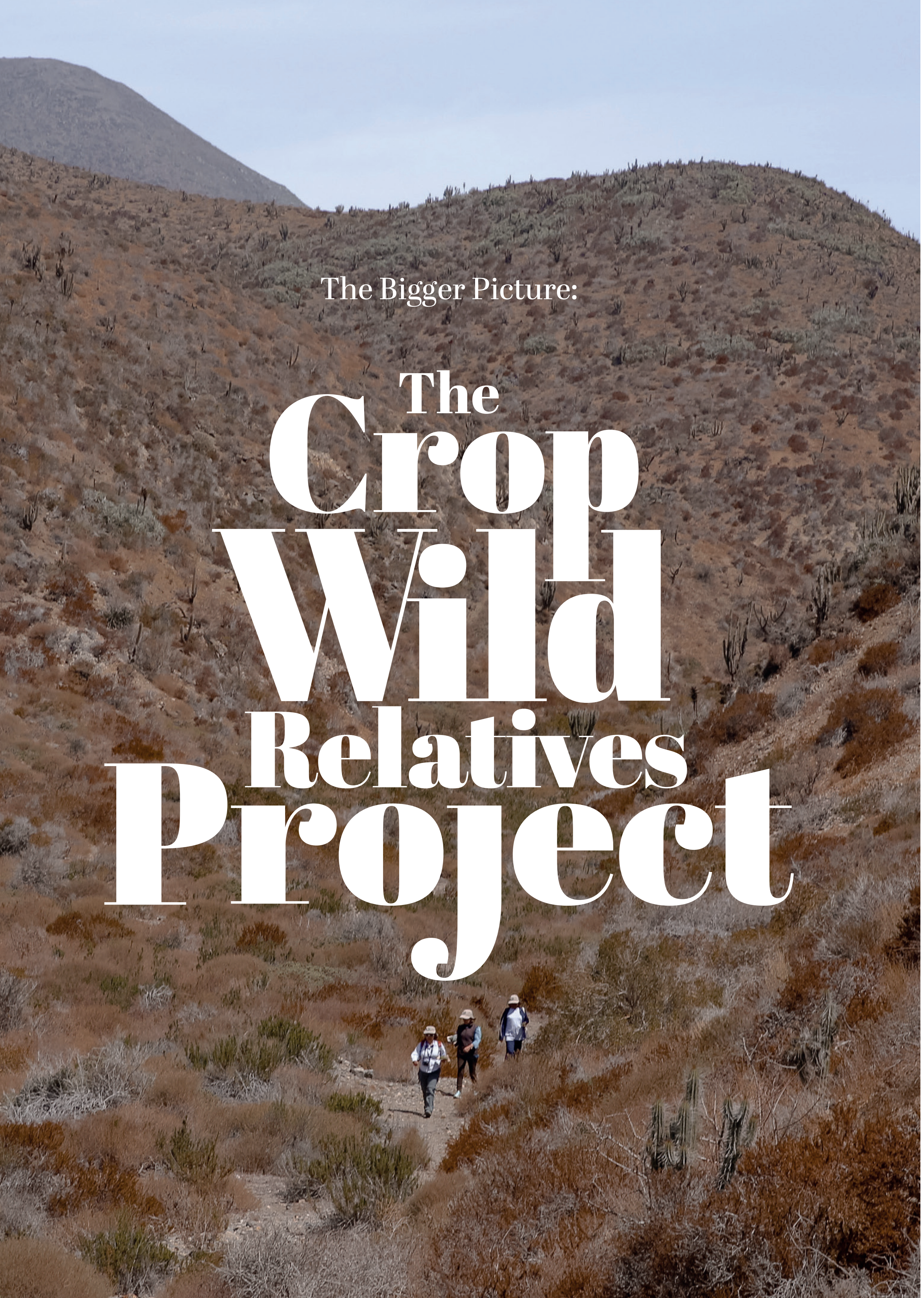
Our partners in Pakistan collected **204 samples of 33 different species.**

FILLING THE GAPS

Every collecting partner had some unique problems to overcome.

But they were brought together by a common goal and a shared commitment to food security.

Hannes Dempewolf, Senior Scientist, Crop Trust



The Bigger Picture: The Crop Wild Relatives Project

The onerous task of collecting the wild cousins of 28 of the world's most important crops is part of a comprehensive, global, 10-year project, funded by the Government of Norway and coordinated by the Crop Trust in collaboration with Kew's MSB.

Started in 2011, the CWR Project consists of five components, which together form a habitat-to-breeder pipeline: from identifying CWR that were missing or underrepresented in the world's genebanks, to collecting them in nature, to conserving them, to using their genetic diversity in breeding programs, to finally sharing seeds and the resulting data. In the following pages we provide an overview of these components.

> The CWR Project has no precedent. It is a long-term, forward-thinking initiative that supports the activities of hundreds of actors across the world in a comprehensive manner.

Walter de Boef, external reviewer of the CWR Project

THE BIGGER PICTURE: THE CROP WILD RELATIVES PROJECT

1

Prioritizing

To kick off the project, the occurrence of CWR was assessed in existing collections and compared to the potential geographic distribution of each species. This “gap analysis” focused on the genepools of 81 of our most important food and forage crops and was key to identifying which CWR were of highest priority for collecting and where to find them.

> Despite the historic efforts to conserve them, many important CWR are still underrepresented in, or altogether missing, from genebank collections.

Nora Castañeda-Álvarez, lead researcher in the global study on CWR conservation priorities

2

Collecting

During the collecting phase, national partners in 25 countries searched for the missing CWR. To help meet their objectives, many national partners participated in training courses in seed collection and processing organized by Kew’s MSB staff. Additionally, MSB provided country-specific collecting guides to help identify and locate plants in the field. After six years, the collecting phase came to an end in 2018. In total, our partners collected 4,644 CWR samples.

3

Conserving

After collecting the CWR, our partners ensured the seeds were properly conserved so that they would be available for breeding and research into the long-term future. Thanks to the CWR Project, the seeds are now conserved in the national genebank of partner countries, as well as at Kew’s MSB or an international genebank as a backup. The team at Kew’s MSB verified the identification of each sample, conserved a copy of the seeds and re-distributed seed material to other genebanks under the terms of the Plant Treaty.

> In the past, all this diversity was safe in the wild, but now we are racing against the clock to save it from disappearing from our grasslands. If the Irish potato famine happened today, we would rely on seeds in genebanks, like the ones collected under this project, to develop new resistant varieties.

Gustavo Heiden, researcher at the Brazilian Agricultural Research Corporation (EMBRAPA)

4

Pre-breeding and Evaluation

CWR often cannot be directly used in breeding programs. They’re a little too wild; they carry too much unwanted baggage. Instead, a “pre-breeding” step is needed so their desirable traits can be identified, isolated and transferred to intermediate products that are more readily usable to improve modern crop varieties.

More than 100 national and international partners in 48 countries are working under the CWR Project to identify and transfer beneficial traits from CWR into 19 priority food and forage crops to make them more resilient to climate change. The most promising products of this work are already finding their way into advanced breeding programs targeting climate change adaptation and will soon be in the hands of farmers.

Sharing Data

A LOT of data is being produced by the CWR Project. Managing and analyzing this data is crucial to ensuring that the diversity being conserved and used continues to be available and shared. Under the CWR Project, national partners received support to improve their information systems and data management.

The online platform, **Genesys**, aggregates information from dozens of genebanks around the world.

Genesys now includes a page which makes basic information about the collected CWR samples publicly available.

As for the genetic and performance data on the results of the pre-breeding work, that’s available on **Germinate**, a platform developed by the James Hutton Institute in the UK, for 14 of the 19 CWR Project’s pre-breeding crops.

How to Conserve Crop Wild Relatives

The ultimate goal of the collecting effort in each country was to add as many samples of viable seeds as possible to genebanks for long-term conservation.

Once collectors successfully spotted a plant they were after, the conservation process could begin. Straight away in the field, or back at their home institutions, seeds were cleaned, dried and treated to eliminate pathogens.

If enough seeds were collected during the expedition, the dried seeds were preserved in air-tight containers and stored at sub-zero temperatures in their national genebank.

If researchers were able to only collect a few seeds, they had to make plans to multiply them back home. If they were not able to collect seeds at all, sometimes they brought the whole plants back to their research station to produce seeds under controlled conditions. Otherwise, they had to plan to go back at a better time. The researchers were careful not to collect more than 20% of the available seed from any population, so they wouldn't deplete the wild population.

As a resource for future identification efforts, herbarium specimens were made from all populations collected. These are samples of intact plants that are pressed, dried and saved for future reference.

To ensure the long-term access to all conserved material – field observations, seeds, herbarium specimens – and to facilitate sharing of resources, the next step was to digitize all collected information.

Sharing the Diversity

The efforts of national partners do not just enrich their national genebanks – they also benefit the global community, as all the material they collected can now be shared with others according to well-established rules.

These rules are provided by the Plant Treaty, which provides a framework for how to provide access to crop diversity in genebanks and how to share the benefits arising from its use.

Each CWR sample collected during the project was divided into three lots. One lot entered the national genebank of the collecting country, while the other two were shipped to Kew's MSB – or, in some instances, directly to international genebanks. Staff at Kew's MSB kept one lot for long-term storage, and the last was forwarded to international and national genebanks.

These genebanks have, in turn, added the newly acquired materials to the collections they safeguard and will make them available to current and future breeding and research programs, all under the terms of the Plant Treaty. For some of our national partners, this was the first time that they have actively contributed to the global system of conservation and use that the Plant Treaty and the Crop Trust are helping to build.

Learn more about the International Treaty on Plant Genetic Resources for Food and Agriculture at http://www.fao.org/plant-treaty/en/

These partner genebanks are now actively and purposefully contributing to the multilateral system [of the Plant Treaty]. That's an important threshold event from a policy standpoint and a significant national achievement.

External CWR Project review, 2019

From the World to Kew, to the World

When seeds arrive at Kew's MSB in West Sussex in the United Kingdom, staff carry out some standard checks. For example, they may measure viability or grow some plants from seeds if there was uncertainty about the identity of the plant. Some CWR are really difficult to tell apart.

Thus far, Kew's MSB has distributed a total of 3,283 samples of 165 species to nine genebanks around the world.

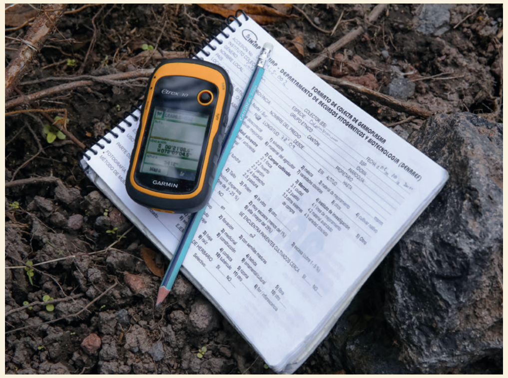
The genebanks of the following organizations have received samples:

- International Center for Agricultural Research in the Dry Areas (ICARDA, Morocco and Lebanon)
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, India)
- International Rice Research Institute (IRRI, Philippines)
- International *Musa* Germplasm Transit Centre (ITC, Belgium)
- Leibniz Institute of Plant Genetics and Crop Plant Research (IPK, Germany)
- Plant Gene Resource of Canada (PGRC)
- South Australian Research and Development Institute (SARDI, Australia)
- U.S. Department of Agriculture (USDA, United States)
- World Vegetable Center (WorldVeg, Taiwan)

The opportunity to work with so many partners all over the world has been fantastic. Many countries have now realized how important crop wild relatives are – and what an invaluable source they are for breeders.

Chris Cockel, CWR Project Coordinator, Kew's MSB

Saving all Collecting Data, Forever



The wealth of plant diversity collected thanks to the CWR Project can only do some good for farmers if it is available to users, be they researchers or breeders. That starts with knowing in which genebank it can be found. But that's not enough. Material also has to be attractive to potential users.

One of the things that determines how attractive a seed sample on the shelves of a genebank is to users is the amount of data associated with it. Nobody likes seeds about which little is known. And it doesn't have to be fancy data. "Passport data" is often enough to pique the interest of a breeder. That includes detailed information about the collection site, including coordinates and altitude, as well as taxonomic identification. This can point to populations that may be resistant to a climatic stress or to a pest or disease.

To provide easy access of such information to breeders, researchers and policymakers, the Crop Trust manages the online platform Genesys. The data in Genesys is not limited to CWR but aggregates passport data on millions of samples stored in hundreds of genebanks around the world. Currently, 3,477 samples collected under the CWR Project are searchable through Genesys, and the number is growing. Genesys is an essential tool in facilitating sharing of seeds and data.

Explore the world's crop diversity at https://www.genesys-pgr.org

The more information you gather, the more useful it will be for future collectors and plant breeders, who wish to know when, where and how these plants were collected.

Alvaro Montero, seed collector from the National Institute of Agricultural Research (INIAP), Ecuador

The Queen of Forages Already Made It

Plant material collected as part of the CWR Project is expected to make it from the field to the genebank to the breeder, and finally to farmers' fields, as part of an improved, climate-proof variety. Here we highlight an example of a crop whose collected wild relatives are already making a difference.

Alfalfa, or *Medicago sativa*, is a high-yielding animal fodder with high nutritional quality. More than 80 countries rely on the "queen of forages" to feed their livestock. Alfalfa is particularly important for subsistence farmers in areas of poor soils where a healthy cow, sheep or goat often means a healthy family. There's high demand for better adapted seed able to cope with extreme weather, but breeders have lacked stress-tolerant alfalfa to work with.

The gap analysis identified that alfalfa wild relatives were of high priority for collection and conservation, and nine of the collecting partners included them in their target list. On the hunt for these tiny plants, collectors often had to cope with scant information. In the case of Georgia, once pristine beaches on the Black Sea had been turned into tourist areas, which pushed the wild alfalfa that had thrived in coastal areas to the edge of extinction. The collectors' dedication, in Georgia and in the eight other countries, led to 356 samples of 20 different alfalfa species being collected and safeguarded.

As early as 2013, the University of Pavia (Italy) sent their first wild alfalfa samples to Kew's MSB, which immediately made them available to the South Australian Research and Development Institute (SARDI) under the terms of the Plant Treaty.

Under the CWR Project's pre-breeding component, researchers at SARDI set out to cross some of these diverse wild alfalfa species with modern varieties. The resulting "pre-breeding lines" are currently being "stress-tested" in the field – in Australia, as well as in Chile, China and Kazakhstan.

Already, some of the new crosses have exceeded all expectations: they have survived temperature ranging from -38 to +35 degrees Celsius and still delivered high yields. Whilst a first pre-breeding phase was successfully completed in 2018, ongoing efforts aim at further developing the most promising pre-breeding lines, multiplying seeds of the improved alfalfa, distributing the newly generated seed material to farmers and breeders around the world, and evaluating these in multi-environmental field trials involving small-scale farmers.

356 total samples collected
20 different species
9 countries collected wild relatives of alfalfa

Becoming a Collecting Expert

Collecting and conserving plant seeds require expert knowledge, both in the field and when descending into the sub-zero vaults where seeds are stored long term.

Capacity Building and Support on the Ground

When it comes to working with CWR, the challenges quickly multiply. Most of the collecting partners had never searched for, much less collected, CWR. For the project to be a success, a thorough immersion into state-of-the-art techniques for collecting, processing and storing seeds was key.

Kew's MSB is the largest genebank in the world specializing in the seeds of wild plants. The MSB Partnership is a global plant conservation program involving partners from nearly 100 countries. The staff at Kew's MSB are highly experienced in supporting national partners, not only to collect high-quality and diverse seeds, but also build institutional capacity so that these efforts can continue once the direct support comes to an end.

As part of the CWR Project, Kew's MSB staff organized training courses both at Kew and in partner countries. They also provided ongoing support to all partners in the field throughout the collecting phase of the project.

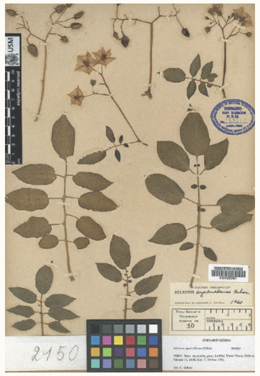
Training courses took place in Vietnam, Malaysia, Azerbaijan, Georgia, Chile and Australia.

In total, Kew's MSB staff gave hands-on training to 174 participants from the 25 national partners in seed collecting, cleaning and drying, and in making herbarium specimens. In addition, they provided country- and species- specific collection guides, as well as equipment kits to facilitate processing of the seeds.

Our partners know their countries and they know about the flora of their countries. We know about seed physiology, about collecting seeds of wild plants. So joining forces in this experience benefits us all.

Kate Gold, former Head of Conservation and Technology, Kew's MSB, during a training course in Uganda in 2014 with participants from Africa.

Tailored Collecting Guides



Identification details for a wild relative of potato, *Solanum ayacuchense* Ochoa, featured in the Peru Collecting Guide. It was classified as endangered and faces a high risk of extinction in the wild.

Where do you even start to look for crop wild relatives?

And when should you be there? And once you find, and correctly identify, the tiny plants that look nothing like our modern barley or potato, how do you collect their seeds? By shaking, by cutting or by bagging the whole seed head? The population you find might only contain a few plants, so every seed is precious and better not be wasted!

To maximize collecting success, Kew's MSB staff compiled all relevant knowledge in country-specific collecting guides, which could be printed or used on tablets and smartphones. These guides went out to all partner countries, as well as four non-project partners – South Sudan, Mozambique, Myanmar and Sri Lanka. They contained detailed information on the CWR in each country. For every featured species, there was a distribution map (based on previous findings but also modeled habitat predictions), photos and historic herbarium vouchers to aid identification, as well as practical advice on how and when to best harvest the seeds.

The challenges are huge in the field because the populations are little known. Verifying their identity is a big challenge. One must use very robust procedures that come from the most modern science, and up-to-date knowledge.

Michael Way, Conservation Partnership Coordinator for the Americas, Kew's MSB, during the training course in Chile.

Collecting seeds,

Quick & Clean

In addition to the collecting guides, Kew's MSB staff provided national collecting partners with robust and easy-to-use equipment kits. Everything needed for collecting, cleaning and drying seeds was packed neatly into large blue drums, which could be used in the field as well as back at their home institutions to dry seeds before they went for storage. Correct handling of the seeds after harvest maximizes the longevity of the collection.

1. Blue drum - 60-liter air-tight container to hold all the equipment and supplies. **2. Silica gel** - To dry the seeds. **3. Cloth bag / paper bags** - All seed samples have to be kept separately. Bags are placed inside the drum for up to a month to dry properly. **4. Hand lens** - To identify plants and determine whether the seeds are ripe and at an appropriate stage to collect. **5. Dissection kit** - To separate the good seeds from the bad ones and to precisely check anatomy of plants. **6. Secateurs** - To cut large samples, for example to make herbarium specimens. **7. GPS** - Accurate coordinates of the collecting site inform future collecting missions and geo-reference the plant samples. **8. Herbarium press** - Whole plants are pressed and dried for later identification and reference purposes. **9. Hygrometer** - Measures the humidity in the drum. Drying is essential to seed longevity. **10. First aid kit** - To treat minor injuries. **11. Sieves** - To clean the seeds. **12. Double-ended brush** - To clean equipment, particularly sieves. **13. Rubber bung** - Small but essential: perfect weight to rub over dried plant material to release the seeds without damaging them. **14. Foil bags and clips** - Once the seeds are dry enough, they are tightly sealed for long-term storage.

Lessons Learned

The challenges the collectors faced were many and varied. Each species, each region, each collecting trip put new and often unexpected obstacles in their way. Now that the last bags of seeds are being processed, and national partners have had a moment to catch their breath, they can reflect on what this unique experience has taught them.

Planning can never be thorough enough. The more information on species occurrence and appearance, flowering time and native habitat that could be compiled, the easier it was to find and identify the often tiny and unremarkable plants in the field.

Flexibility is absolutely required, and most itineraries had to be changed, often at the shortest of notice. And changed again. Extreme climate was the biggest reason, as unfavorable weather conditions made it either impossible to reach remote locations or left plants underdeveloped and with little or no seed. Collectors had to proactively reschedule their trips or expand their search areas, and multiple site visits were often necessary to collect sufficient, and sufficiently mature, seeds.

Time passes quickly – sometimes too quickly. Researching these often little-known plants added to the preparation time, and extra time was needed to secure enough seeds in the field or to do a repeat visit. Where plants could only be picked as tubers or cuttings, extra time in the greenhouse or experimental field site was needed to regenerate the plants and multiply seeds.

Local knowledge is essential to ensure the success of collecting expeditions. In many countries, involving local communities, farmers and the traditional doctors in the planning stages, and in collecting trips themselves, greatly enhanced the chance of finding the plants at the right time and in unplanned places. Project resources could be used more efficiently, as local experts knew best when plants would carry mature seeds. In some cases, the local collaborator would update the collectors throughout the growing season, so they would only need to travel to remote areas when the seeds were just ready for harvest. Sometimes, all that prevented a collector from missing out on an elusive crop wild relative was a young shepherd and his knowledge of the area.

Communication is key. Successful collecting requires a wide range of specialized expert knowledge. Decision-makers, local people, botanists, ecologists, geographers, genebank curators and technical staff need to work hand in hand, and engage in open, continuing dialogue.

Conclusion

For six years, partners in 25 countries have been confronting the many challenges of collecting the wild relatives of 28 important food and forage crops.

They have amassed more than 4,600 samples of CWR and are now conserving and distributing them through national and international genebanks under the Plant Treaty.

The skills and experience acquired by the national partners through their implementation of this project has enhanced their technical and project management capacity and positioned them as effective partners for participation in future international and global initiatives involving CWR collecting, processing and conservation.

David Williams, external CWR Project review 2019

This global collecting effort has taken place at a time when wild plants are under severe threat in their natural habitats. Due to pressures such as climate change, land use change and over-grazing, many populations and entire plant species will no doubt disappear in the years to come. Conserving the enormous genetic diversity of the wild relatives of our food crops is crucial if we are to use these invaluable breeding resources to help adapt our modern crops to a changing climate. Much has indeed been achieved, but it is clear that many CWR are still in need of further collection.

The collecting effort described here was part of a comprehensive, multi-year project that empowered national partners around the world to enrich their genebank collections. At the same time, this project has shared those resources with the global community under the rules of the International Treaty on Plant Genetic Resources for Food and Agriculture, to the ultimate benefit of farmers everywhere.

Led by the Crop Trust in collaboration with Kew's MSB, this project is an example of how national and international organizations can collectively contribute to implementing the Plant Treaty. It proves that we can collectively work for the benefit of all. After all, the seed sample that holds the key to adapting a crop to climate change in one country may well come from the other side of the world.

This global undertaking has been possible thanks to the generous funding provided by the Government of Norway.

Reality Check

What are we still missing?
Did national partners collect enough seed material?
Was each species collected from sufficient locations?

Our world is changing rapidly due to climate change and habitat destruction. We really don't have time to rest on our laurels. There are so many unanswered questions.

National genebanks and Kew's MSB continue to evaluate the quality of the seeds collected under the CWR Project. Concurrently, the Crop Trust is re-running the gap analysis to evaluate which gaps in genebanks still remain to be filled.

The CWR collecting expeditions focused on a list of 28 crop genepools. Is that enough? There are other important crops besides these. Take cassava, for example: are its modern varieties fit for a changing climate? Are its wild relatives adequately conserved in genebanks and accessible for breeding programs? Or are they critically endangered in the field?

Work needs to continue. The success of the CWR Project will guide future efforts on how to structure comprehensive, global collecting and conservation efforts and even pre-breeding programs. As a global community we must overcome lack of knowledge, funding and expertise if indeed we want to safeguard and make available the CWR diversity that is out there, for the benefit of all generations to come.

Selected Scientific Publications

Sharing detailed information with the scientific community further promotes awareness and understanding of CWR. To see a selection of scientific publications that are a direct outcome of the collecting phase of the CWR Project -- please visit:

https://www.cwrdiversity.org/resources/cwr-project-publications/

Further Reading and In the Media

Stories

Searching for wild potatoes in Ecuador:
https://stories.cwrdiversity.org/story/ecuador1/

Showcasing the word about crop wild relatives in Pakistan:
https://www.cwrdiversity.org/cwr-in-pakistan/

Climbing up and down Mount Everest twice – in Pakistan:
https://www.cwrdiversity.org/seed-collecting-in-pakistan/

In search of the wild cousins of the "Batata Inglesa":
https://stories.cwrdiversity.org/story/batatas-in-brazil/

A wild potato, bean, eggplant and rice saga:
https://stories.cwrdiversity.org/story/searching-for-crop-wild-relatives-in-central-america/

Sunset of a population in Nepal:
https://www.cwrdiversity.org/sunset-of-a-population/

Tigers, elephants and wild rice:
https://www.cwrdiversity.org/tigers-elephants-and-wild-rice/

The journey of a wild relative: entering the Millennium Seed Bank:
https://stories.cwrdiversity.org/story/journey-wild-relative/

In search of the elusive sea medick on Georgia's Black Sea coast:
https://www.cwrdiversity.org/sea-medick/

Learning seed collecting tricks in Malaysia:
https://www.cwrdiversity.org/workshop-on-collecting-handling-and-long-term-conservation-of-seeds-of-crop-wild-relatives-in-malaysia/

Videos

Animation on what's it all about:
https://www.cwrdiversity.org/new-cwr-project-video/

The challenges of collecting wild relatives:
https://www.cwrdiversity.org/new-collecting-and-capacity-building-video/

Collecting crop wild relatives in Malaysia and Vietnam:
https://www.cwrdiversity.org/new-video-collecting-crop-wild-relatives/

Photos

The CWR Project in color:
https://www.flickr.com/photos/cropwildrelatives/albums

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This is a true legacy project; its outputs will long outlive us all, and help agriculture adapt to challenges brought about by climate change that we can't even imagine now.

And it would not have been possible without the generous funding of the Government of Norway, and the hard work of many committed partners.

Chris Cockel, CWR Project Coordinator, Kew's MSB