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The Svalbard Global Seed Vault: **Securing the Future of Agriculture**

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The Global Crop Diversity Trust

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Executive Summary

This report combines the historical view and a unique moment in the story of agriculture. The formal opening of the Svalbard Global Seed Vault deep inside an Arctic mountain on February 26, 2008 marks a turning point toward ensuring the crops that sustain us will not be lost. It follows millennia of haphazard forms of protecting crop diversity, and decades of catch-up preservation efforts to save more than a million different varieties of crops. With growing evidence that unchecked climate change could seriously threaten agricultural production and the diversity of crops around the world, the opening of the Seed Vault also represents a major step toward finishing the job of protecting the varieties now held in seed banks. A quiet rescue mission is underway. It will intensify in the coming years, as thousands of scientists, plant breeders, farmers, and those working in the Global Crop Diversity Trust identify and save as many distinct crop varieties as possible.

The story of agriculture dates to some 13,000 years ago, when human societies began the transformation from hunting and gathering to forms of growing food. But the story of systematically saving varieties of crops didn't begin until less than 100 years ago. In the 1920s, plant breeders assembled collections of seeds to breed new varieties. Gradually, scientists began to sample and collect more generally in an attempt to assemble the complete diversity of each crop—before distinct varieties were lost.

These scientists delved into the makeup of these varieties. Plant breeders created variety upon variety. Today, the documented pedigrees of modern crop varieties are longer than those of any monarchy. One type of wheat, for instance, has a pedigree that runs six meters long in small type on paper, recording hundreds of crosses, using many different types of wheat from many countries. A number of crops could not be produced on a commercial scale if not for genes obtained from their botanical wild relatives and used in breeding programs.

Around the world, countries and institutions created seed banks, also called genebanks. Today, there are some 1400 collections of crop diversity, ranging in size from one sample to more than half a million. These seed banks now house about 6.5 million samples. About 1.5 million of these are thought to be distinct samples. And within each crop, the diversity of varieties is stunning. Experts, for instance, estimate 200,000 types of wheat, 30,000 types of corn, 47,000 types of sorghum, and even 15,000 types of groundnut.

Some of the more popular varieties are widely distributed in seed banks, occurring in literally hundreds of collections, while others are in just a single facility. Information systems will eventually aid in identifying unintended duplication. About half of the stored samples are in developing countries, and about half of all samples are of cereals.

The Global Crop Diversity Trust is working with the Consultative Group on International Agricultural Research (CGIAR) and seed banks from around the world to assist in preparing and shipping seeds to the Seed Vault in Svalbard. The Trust has assembled leading experts in all of the major crops to identify priority collections. Some 500 scientists from around the world have been involved. The rescue and regeneration effort is under way, and will result in a steady flow of samples being sent to Svalbard in coming years as the genebanks produce fresh new seed. For the February 26 opening of the Seed Vault, workers will load shipments from 21 seed banks, which have sent 268,000 samples that contain about 100 million seeds.

When fully stocked, the Seed Vault will contain samples deposited by large and small genebanks, by those in developed and developing countries as well as international institutions, by those that have state-of-the-art facilities, and by those whose facilities fall far short of international standards. They will share a common desire to use the Seed Vault to insure against losses in their own facility.

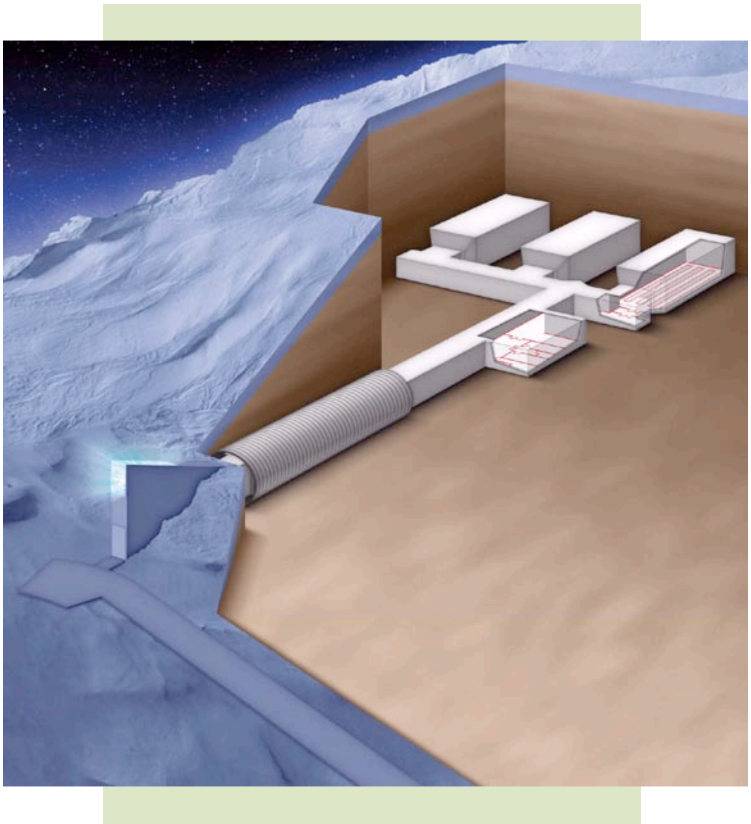
Why do they want a backup? Put simply, without the diversity represented in these collections, agriculture will fail. This diversity is vital in guaranteeing a successful harvest and in satisfying our needs for variety. On one level, consumers want diversity within crops because they need wheat for pasta and wheat for bread (for which they need two types of wheat), or they want tomatoes for eating fresh and for making sauce (again, two types of tomato.) On another, farmers want diversity not just to supply consumer demands, but because different farming and environmental conditions require crop varieties with different characteristics.

Plant breeders help consumers and farmers. They have to produce varieties that are productive and popular. This is a moving target. Pest and diseases evolve, the climate changes and so do consumer preferences, and the plant breeder has to incorporate the appropriate characteristics into the variety he or she breeds. And so a farmer's field, over time, is a study of change. One has to run fast just to stay in the same place, just to beat back the pests and diseases and other constantly evolving challenges.

Three partners are overseeing the Seed Vault: the Nordic Gene Bank, the Norwegian Ministry of Agriculture and Food, and the Global Crop Diversity Trust. They have a simple purpose: provide insurance against both incremental and catastrophic loss of crop diversity held in traditional seed banks around the world. The Seed Vault offers "fail-safe" protection. It serves as an essential element in a global network of facilities that conserve crop diversity and make it available for use in plant breeding and research. Its genesis lies primarily in the desire of scientists to protect against the all-too-common small-scale loss of diversity in individual seed collections. With a duplicate sample of each distinct variety safeguarded in the Seed Vault, seed banks can be assured that the loss of a variety in their institution, or even the loss of the entire collection, will not mean the extinction of the variety or varieties and the diversity they embody.

Svalbard, in the northern reaches of Norway, was chosen for a variety of reasons: The permafrost in the ground offers natural freezing for the seeds; the vault's remote location enhances the security of the facility; the local infrastructure is excellent; Norway, a global player in many multinational efforts, is a willing host; and the area is geologically stable.

In the case of a large-scale regional or even global catastrophe, it is quite likely that the Seed Vault would prove indispensable to humanity. Still, we need not experience apocalypse in order for the Seed Vault to be useful and to repay its costs thousands of times over. If the Seed Vault simply re-supplies genebanks with samples that those genebanks lose accidentally, it will be a grand bargain.



Seeds and Food

For most of human history, people have lived through hunting and gathering. The vast majority of people who have ever lived, lived by such means. Agriculture is a relatively recent phenomenon. The slow transition from hunting and agriculture began "just" 13,000 years ago or so.

There is a big difference between the seed of wild plants and of domesticated plants. Wild plants are engineered to scatter their seeds widely. They "shatter," to use a biological term. Our early hunting and gathering ancestors, however, would have found it easier and more lucrative to harvest seeds that stayed on the plant, seeds that had not already fallen to the ground. Gatherers understood the connection between seeds and plants. By taking the non-shattering harvested seed back to their camps and growing them, or by encouraging nearby stands of such plants in the wild, they would have increased the percentage of these non-shattering plants and correspondingly increased their harvest. Typically, the genetic difference between shattering and non-shattering seeds is spelled out in one or two genes. But this is the difference between wild plants and domesticated crops, a difference that our ancestors took hold of and began to exploit in earnest in the Neolithic period, more than 10,000 years ago.

Domestication usually took place where wild forms of the crop plant were native. Thus, crops originated in certain regions. Rice, soya, banana, and oranges are from China in the Far East. Wheat, barley, and lentil hail from the Near East. Sorghum and watermelon are from Africa. Maize, beans, and potato are from Latin America. Most major food crops originated in what are today known as developing countries, and they have had their longest history there. And it is in these regions of origin that the greatest diversity, the greatest variations in types, have been found and continue to be used.

While agriculture is relatively young, 13,000 years or so is still a long time! In a very real sense, crops and society co-evolved. Crops traveled with people. They encountered new environments, climates, growing conditions, pests, and diseases. They adapted naturally to such factors with considerable but varying degrees of success. Rice, for instance, is grown in over 110 countries in the world.

Crops also became part of different human cultures and the foundation for economies. People selected and encouraged different types for different purposes. Maize is not only adapted to growing in conditions from South Africa to Sweden, from Mexico to China, it also comes in varieties for eating fresh, for grinding into flour, for popcorn, for beer, for making into sugar for soft drinks, and now for fuel for automobiles. And some special varieties of maize have been used in religious ceremonies and for medicinal purposes.

Some crop diversity is visual. Potatoes come in an array of colors, for example. They can be white, red, black, blue, purple, or yellow-fleshed. But different varieties or types have hidden traits. Some may be heat or drought tolerant or resistant to a disease or pest. Others may have enhanced nutritional attributes. And from one variety to the next, you can even taste the difference.

All of these characteristics are produced by the genetic make-up of the plant or variety. When scientists speak of conserving the genepool or conserving crop diversity, they are really talking about conserving all the different traits the crop can exhibit. One does this by conserving the genes that "code" for, that produce, the traits. And one does this, typically, by conserving seeds (or in some cases tubers or other planting materials), which in turn contain the genes.

It is difficult to estimate how much crop diversity exists in the world today, and impossible to know how much used to exist and thus how much has been lost. First, we will never have a "head count" of the diversity that existed 200 years ago, much less 2000 years ago. Just as problematic is the question of what is meant by the word "diversity." At one level it's simple: A Golden Delicious apple is one variety, a Red Delicious is another. Together that makes two. In this example, diversity is displayed as two distinct varieties, each being defined technically as a slightly different combination of genes. But in the fields of many traditional farmers in developing countries, one will not find uniform varieties. Instead one will find mixtures. A wheat field may contain a number of different types, maturing at different times, with different degrees of pest and disease resistance. Does one consider this population of plants to be one variety, or many? Finally, many modern varieties are essentially alike. They may differ in only one or two minor attributes, whereas some of the more traditional varieties, or populations, can be remarkably distinctive from one another. These differences explain why it is difficult from a scientific standpoint to answer the simple questions: How many varieties are there? And, how many have been lost?

Illustration 1. Wheat collected in a farmer's field in the Badakshan province of Tajikistan. Seven "varieties" or one? In a genebank, this "population" would typically be considered and managed as a single sample. Thus, the number of samples, while large, masks an even greater diversity.

Table 1. U.S. Vegetable Varieties Lost (presumed extinct)

Crop	Total Varieties in 1903	1903 Varieties in US Collection in 1983	Varieties Lost (%)
Beans	578	32	94.5
Beets	288	17	94.1
Cabbage	544	28	94.9
Carrot	287	21	92.7
Sweet Corn	307	12	96.1
Lettuce	497	36	92.8
Onion	357	21	94.1
Peanut	31	2	93.5
Squash	341	40	88.3
Tomato	408	79	80.6
Watermelon	223	20	91.0

Still,everyone wants and needs to have some order-of-magnitude sense of how much diversity, or at least how many "varieties" or types there are out there. Recently, the Global Crop Diversity Trust asked the heads of some major genebanks to answer the unanswerable question. How many varieties of rice, of beans, of wheat, etc. are there? Understandably, the experts were reluctant to talk in these terms and when they did respond they put numerous caveats on their responses. But they did give estimates:

- Rice: >200,000
- Wheat: 200,000
- Sorghum: 47,000
- Bean: 30,000
- Chickpea: 30,000
- Maize (corn): 30,000
- Pearl millet: 20,000
- Groundnut (peanut): 15,000
- Cassava: 8,000

We know that much diversity has been lost over time. A study that correlated varieties grown in the U.S. in the 1800s with varieties stored in genebanks in the early-1980s indicated that a huge number of the varieties had been lost.

The loss of varieties is not exactly the same thing as the loss of genetic diversity. The traits and genes in the extinct varieties might still be found in varieties that continue to exist. That is, the genes may not have become extinct, just the unique *combination* of genes that defines a variety might have been lost. It's possible. But varietal loss is a surrogate for loss of real diversity. It is unlikely that such large percentages of crop varieties could be lost without the permanent loss of characteristics. And, to be sure, the combination itself is important. Losing it is not trivial. Varieties once lost are virtually impossible to create, such is their complexity.

When it comes to the diversity found in developing countries, it is much easier to say that a massive amount of crop diversity has been lost, forever. Until the 1960s, most farmers in developing countries were cultivating highly diverse populations. The widespread replacement of these populations with modern uniform varieties has resulted in significant genetic erosion, the permanent loss of a huge amount of crop diversity.

As Lloyd Evans explains in his book, *Feeding the Ten Billion*, people have employed different strategies to produce more food as populations have grown. In fact, there are only six possible strategies. Until the middle part of the twentieth century the easiest and most effective one was to cut down the forests and expand cropland. There is a natural limit to this kind of strategy, and it was reached. In recent decades, global food production has increased primarily because of improvements in yield due to new varieties and more productive farming systems. About 50 percent of the increase in production is attributable to new, higher-yielding varieties.

Thus began a process in which farmers replaced traditional types with modern, scientifically-bred varieties. In many instances, it was a perfectly natural and reasonable thing to do. But it had the unintended consequence of undermining the biological foundation upon which the modern varieties were based. Quite literally, the modern variety contains traits—genes—assembled from older varieties and populations. Therefore, unless crop diversity is collected and conserved, the traits it contains are lost and cannot be incorporated into future varieties. We have, as crop scientist Garrison Wilkes pointed out many years ago, a situation in which we are "taking stones from the foundation in order to repair the roof."

Table 2. Six Components of Increasing Food Supplies

Options	Comment
1. Increase yield on existing lands, per crop	*Crop diversity needed for breeding*
2. Increase number of crops grown on the land (e.g., shorter season crops)	*Crop diversity needed for breeding*
3. Reduce post-harvest losses	*Crop diversity needed for breeding*
4. Displace lower yielding crops by higher yielding ones	*Crop diversity needed for breeding*
5. Increase area of land under cultivation	*Crop diversity needed for breeding* (to adapt crops to new areas) But this option comes with high environmental cost and cannot be a major contributor in the future.
6. Reduce use of grains fed to animals	Increase in affluence globally means we are now going in the opposite direction, fast.

Importance and Use of Crop Diversity

Consumers want diversity within crops. They want wheat for pasta and wheat for bread (two different types); they want tomatoes for eating fresh and for making sauce; and they like tart and sweet apples. Farmers want and need diversity not just to supply such marketplace demands but because different farming and environmental conditions require different crop varieties with different characteristics in order to produce a successful harvest.

Plant breeders address both constituencies. They have to produce varieties that are productive and profitable for the farmers. This is a moving target. Pest and diseases evolve, the climate changes and so do consumer preferences, and the plant breeder has to incorporate the appropriate characteristics into the variety he or she breeds.

There is a constant turnover of varieties in farmers' fields. Some liken this to the Red Queen strategy in *Alice in Wonderland*: one has to run faster and faster just to stay in the same place. Indeed, the battle that plant breeders and farmers wage with pests and diseases through the development of resistant varieties cannot ever be won permanently. There is no single best variety, at least not for long. Today's winner eventually succumbs and is replaced by new, more productive, more resistant varieties incorporating genes or characteristics from a number of previous varieties. This system depends on plant breeders and the raw material they have with which to work—crop diversity.

Breeders work either for public institutions or private companies. For some crops, such as maize, there are hundreds of men and women working to produce new varieties. For other crops, there are alarmingly very few breeders. Only about six people are breeding bananas, despite the fact that bananas are the developing world's fourth most important crop in terms of production value. Nearly 100 million tons are produced annually. It is the staple crop of 400 million people and a major income producer for many more. And only six scientists are breeding yams, despite the fact that 40 million metric tons are produced annually (mostly in Africa,) enough to fill every train freight car in North America.

Plant breeders are the primary direct users of genebanks. In a given year, they obtain about a quarter of a million samples to test and use in their breeding programs. But the diversity found in genebanks is also the foundation of a great deal of basic biological research. More than a quarter of the scientific papers published in four leading international natural science journals give evidence of having been based on samples obtained from genebanks.

So why do genebank collections have to be so large? Why is so much diversity needed? Why not just save "the best"? Interestingly, it's not a question typically posed to the director of an art collection. We don't ask the director, why so many paintings? Couldn't we get by with a representative sample of Picasso and Rembrandt? Perhaps we could in art, though at a cost to

"These resources stand between us and catastrophic starvation on a scale we cannot imagine. In a very real sense, the future of the human race rides on these materials."

Who would survive if wheat, rice or maize were to be destroyed? To suggest such a possibility would have seemed absurd a few years ago. It is not absurd now. How real are the dangers? One might as well ask how serious is atomic warfare. The consequences of failure of one of our major food plants are beyond imagination."

--Jack Harlan (1917-1998) President of the Crop Science Society of America, member of the National Academy of Sciences, chair of the Third International Technical Conference on Plant Genetic Resources, professor of plant genetics society. But in agriculture, diversity is necessary. Absolutely necessary.

The future cannot be predicted. Conditions change. In agriculture, this is particularly true. This is why there is no such thing as the best variety. The best variety today may be the best only in a certain place and a certain time. Tomorrow it may be obsolete, its pest resistance overcome by evolution in an insect species, its ability to be productive compromised by a change in climate. And this is why the collection, maintenance, and *use* of diversity are necessary.

The pedigrees of modern crop varieties are longer than those of any monarchy. For instance, Veery wheat, which is one variety of the crop, has a pedigree that runs six meters long in small type on paper, recording hundreds of crosses using many different types of wheat from many countries. A number of crops probably could not be produced on a commercial scale were it not for genes obtained from their botanical wild relatives and used in breeding programs.

Collecting and Conserving

While much diversity was undoubtedly lost in the last century as agricultural systems around the world "modernized," and as traditional and diverse varieties were replaced by fewer and more uniform modern varieties, much diversity was collected and conserved in genebanks, sometimes called seed banks because for the most part they store seeds. The diversity in these facilities now constitutes the foundation upon which most of the food production in this world is based. Without this diversity, it is inconceivable that agriculture would be able to maintain or improve its productivity. Supporting more than 6 billion people today, or 9 billion people not so long from now, would be out of the question. So regardless of how much diversity once existed, and despite how much has been lost, what's left is what we have to keep agriculture going now and for as far as we can imagine into the future.

Modest seed collecting began in the 1920s, initially for the immediate purpose of assembling traits that plant breeders wanted to breed into new varieties. Gradually, as those new varieties replaced existing diversity (because so many farmers saw the new varieties as improvements over what they were growing,) scientists began to sample and collect more generally for conservation purposes in an attempt to assemble the complete diversity of the crop, not for immediate use but "just in case" it was needed in the future.

Today, there are 1400 collections of crop diversity ranging in size from one sample to more than half a million. In total, genebanks now house about 6.5 million samples. About 1.5 million of these are thought to be "distinct" samples. Some of the more popular ones are widely distributed, occurring in literally hundreds of collections, while others can only be found in a single facility. Information systems are under development now that will aid in identifying unintended and excess duplication.

About half of the stored samples are in developing countries. About half of all samples are of cereals.

A number of the major genebanks, such as the international research centers of the Consultative Group on International Agricultural Research (CGIAR) as well as certain national facilities, operate at a high international standard. Not surprisingly, these are the genebanks that crop breeders and researchers turn to most often to access the genetic resources they need.

For the majority of collections, however, life is more tenuous. Most genebanks do not operate according to international standards for long-term conservation in keeping seeds cold and dry to maintain viability over time. They cannot consistently maintain proper temperature and humidity levels. When seed viability declines, they are unable to produce fresh seed in a timely manner to replace deteriorating stocks. They cannot meet phytosanitary requirements for import or export of seeds and planting materials, etc. Management systems are often poor, staff underpaid, and the budget inadequate. In a world concerned with economic development and the "bottom-line," it is ironic that conservation of crop diversity receives so little priority given the fact that the cost of proper conservation is tiny compared to the benefit stream.

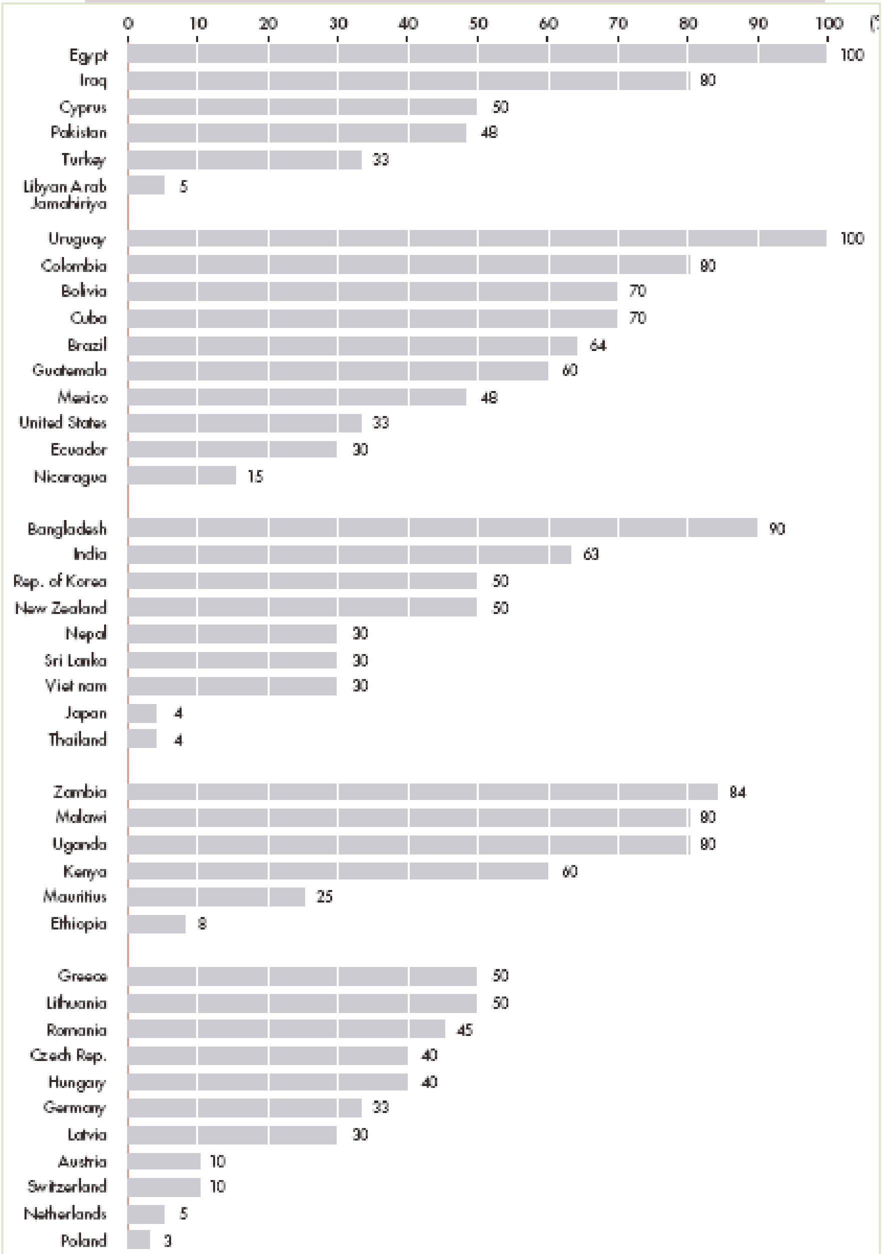
A study published in the *American Journal of Agricultural Economics* found that the value of adding a single sample to the U.S. soybean collection simply to search for resistance to a single pest would likely exceed costs (collection, conservation, and screening) 36-61 times over. And this is conservative. Samples can be screened for more than a single trait, and the samples themselves are made available to researchers all over the world. Similarly, another study found that adding just 1000 new samples to the genebank at the International Rice Research Institute would generate an annual stream of benefits to poor farmers of USD $325 million.

Every genebank, even the best, eventually loses some samples. It seems almost inevitable. In more marginal facilities, the losses can be silent and substantial. Poor conditions cause the seed to deteriorate, and they slowly lose the ability to germinate. Because seeds in a sample are not always uniform, the seeds that die first may be different from the rest. The loss of germination ability may be genetically linked with other traits that disappear as the first seeds in the sample begin to succumb to poor conservation conditions. And *those* traits may be useful ones that should not be lost.

Many national genebanks have reported to the Food and Agriculture Organization of the United Nations that the percentage of seed requiring regeneration (growing plants, harvesting new seed, and refreshing genebank samples) is alarmingly high, indicating that something serious is going wrong…and that diversity is dying.

The major threats and the principal causes of loss of diversity in genebanks have to do with institution-specific management, infrastructure, and funding problems. They are not catastrophic or apocalyptic; they are not the stuff of newspaper headlines. But they are deadly nonetheless. For example, an *in vitro* root and tuber collection was lost in Cameroon due to a

Chart 1. Percentage of accessions in national collections remaining to be regenerated



From: FAO 1997. State of the World's Plant Genetic Resources for Food and Agriculture.

weekend power outage. Such accidents can affect developed countries as well. The temperature in Italy's genebank in Bari, home to 80,000 samples, shot up from minus 20 degrees Celsius to 22 degrees Celsius in July 2004 when the refrigeration equipment malfunctioned. It took months for repairs to be made.

Political instability and disasters pose threats to genebanks as well. Burundi's collections were destroyed during the troubles of the early 1990s. Genebanks in Afghanistan and Iraq were destroyed in recent years, both victims of chaos and looting during war. The national genebank of the Philippines was severely damaged in a typhoon in September 2006.

When samples or entire collections are lost, genebanks usually try to reestablish them. If they know where a duplicate is held, they contact that genebank and ask for some seeds to be sent. But, if records are poor, or if no provisions were previously made for safety duplication, the loss becomes permanent.

In recent years, CGIAR genebanks restored genetic resources to a number of countries that have lost collections. A conservative listing of the countries includes:

Afghanistan, Argentina, Bolivia, Botswana, Brazil, Cambodia, Cameroon, Chile, Dominican Republic, Ecuador, Eritrea, Ethiopia, Gambia, Guatemala, Guinea, Guinea-Bissau, Honduras, India, Iran, Iraq, Kenya, Liberia, Mali, Mexico, Myanmar, Nepal, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sri Lanka, Sudan, Tanzania, Turkey, Uruguay, and Zambia.

In many cases, national genebanks hold seeds that have a long history in the country and are peculiarly adapted to conditions there. The loss of such diversity is particularly unfortunate, because such samples may prove essential in the future breeding of crops tailored to the specific environments and cultures within that country. The destruction of an entire genebank, such as those in Afghanistan and Iraq, inevitably means the loss of unique, indigenous crop diversity important in restoring plant breeding and sustainable agriculture in the country.

No individual genebank—no single physical structure—can provide an iron-clad guarantee of safety. Not even the best-maintained genebanks in the world are immune to all potential problems. Genebanks are lucky in that no political or religious group is against the conservation of seeds. But genebanks can get caught in the middle of a fight. And, many of the best genebanks are located in countries that are experiencing or recently have experienced war or civil strife.

The CGIAR's genebanks, which house some of the largest and best collections of the major crops, are located in Colombia, Ethiopia, India, Kenya, Mexico, Nigeria, Peru, the Philippines, and Syria. These international collections are held "in trust" by CGIAR and are available to all. Technically, the genebanks are among the best in the world. Physically, they could be located in harm's way.

In devising a global system for the conservation of crop diversity, one has to consider the diversity of each crop, one by one. No single genebank regardless of its size contains all the diversity of a crop. Any crop. Even large genebanks conserve only a small percentage of the worldwide holdings or samples of a crop, as Table 3 show.

Table 3. Percentage of the world holdings, by country and crop

	Wheat	*Rice*	*Corn*	*Bean*	*Pea*	*Soybean*
Australia	3	<1	<1	1	4	1
Canada	2	<1	<1	<1	<1	<1
UK	1	<1	<1	<1	4	<1
USA	5	3	5	1	4	13
Brazil	1	2	2	2	2	2
China	1	11	3	3	5	14
Ethiopia	1	<1	<1	<1	1	<1
India	2	5	9	<1	2	1

Sources: FAO State of the World's Plant Genetic Resources, 1998, and Bioversity International Directory of Germplasm Collections where data is missing in first source

Thus, in order to conserve the diversity of a crop, it is necessary to conserve those collections that together encompass the maximum amount of diversity found in the crop samples stored in genebanks. It is not feasible to conserve permanently 6.5 million samples spread amongst 1400 facilities, certainly not if one tries to do it by "conserving" 1400 facilities. But it is feasible—technically and financially—to identify and conserve a much more limited number of distinct samples and arrange for their long-term conservation in a smaller number of institutions.

In practice, this means safeguarding three different types of collections. The first are those held by the CGIAR centers, which in most cases are the largest and most diverse for the crops in which they specialize. They are also the most accessed and utilized collections in the world. The second group consists of large and important collections held and well-managed by a number of developed country institutions as well as by certain large developing countries. A third group involves smaller collections of unique samples held by developing countries. In many cases such a country will hold one or two "globally" important high priority collections. The vast majority of the diversity of a crop is held by these three groups of genebanks, principally the first two.

This is where the Global Crop Diversity Trust comes in.

In October 2004, the Trust was born with a mission that was apparently straightforward—but actually extraordinarily difficult: conserve in perpetuity the Earth's most crucial agricultural biodiversity. One important goal, then, became to provide a secure and sustainable source of funding for the world's most important crop diversity collections. Funding from the Trust, which set up headquarters in Rome, will support basic conservation costs in national and international collections of crop diversity. The Trust will also provide funding to rescue and salvage collections currently at risk, and build capacity in developing countries to manage such collections.

Toward these ends, the Trust worked with the Norwegian government and the Nordic Gene Bank to establish the Svalbard Global Seed Vault, which will serve as a backup holding vault containing duplicates of a wide range of varieties of seed. And through a grant from the UN Foundation and the Bill & Melinda Gates Foundation, it started to support the rescue, regeneration, and safety duplication of unique crop diversity samples held in developing countries. The Trust assembled leading experts in all of the major crops to help it identify priority collections for this initiative. In all, some 500 scientists worldwide have been involved. The rescue and regeneration effort is under way and will result in a steady flow of samples being sent to Svalbard in coming years as genebanks produce fresh new seed.

Svalbard Global Seed Vault

The purpose of the Svalbard Global Seed Vault is to provide insurance against both incremental and catastrophic loss of crop diversity held in traditional seed banks around the world. The Seed Vault offers "fail-safe" protection for one of the most important natural resources on earth. It serves as an essential element in a global network of facilities that conserve crop diversity and make it available for use in plant breeding and research.

Its genesis lies primarily in the desire of scientists to protect against the all-too-common small-scale loss of diversity in individual seed collections. With a duplicate sample of each distinct variety safeguarded in the Seed Vault, seed banks can be assured that the loss of a variety in their institution, or even the loss of the entire collection, will not mean the extinction of the variety or varieties and the diversity they embody. The Seed Vault will have a "spare" copy that can be restored to the seed bank that deposited it. When fully stocked, the Seed Vault will contain samples deposited by large and small genebanks, by those in developed and developing countries as well as international institutions, by those that have state-of-the-art facilities, and by those whose facilities fall far short of international standards.

In the case of a large-scale regional or even global catastrophe, it is quite likely that the Seed Vault could prove indispensable to humanity. The Indian Ocean earthquake on December 26, 2004, which sent massive tsunami waves of up to 30 meters that killed more than 225,000 people in 11 countries, underscores the vulnerability to disaster. The looting of the Iraq and Afghanistan seed banks shows the vulnerability to man-made upheaval. Indeed, those who first gathered together in 2004 to consider the feasibility of establishing such a facility were mindful of a wide spectrum of what could go wrong and why a backup vault for seed collections was necessary.

Given its location and construction, the Seed Vault would likely survive almost anything. Of course, there can never be any absolute guarantees. But the basic point is that we don't need to experience apocalypse in order for the Seed Vault to be useful and to repay its costs thousands of times over. If the Seed Vault simply resupplies genebanks with samples that those genebanks lose accidentally, it will repay our efforts a thousand fold.

> *In undertaking this study, the Committee recognized and accepted the compelling need of the international community to plan for the "worst case scenario," the need to ensure the long-term conservation of plant genetic resources, protecting them from both old and new threats, routine as well as unprecedented occurrences. The Committee, therefore, undertook to assess whether a facility located in Svalbard might provide ultimate "fail-safe" protection for the world's most valuable natural resources, and whether it might be able to do so in a manner that is efficient, sustainable, inexpensive, and politically and legally acceptable.*
>
> *Our conclusion, detailed in this report, is that a Svalbard facility can provide all of these things, and can thus make a major contribution to food and environmental security and to the safety and well-being of human beings for as far into the future as we can see…*
>
> --Fowler, George, et. Al. 2004

The Value of the Vault

There are more than 1000 facilities conserving crop diversity. Most crop diversity is conserved in the form of seed. Properly dried and frozen, seed of most crops can be conserved for many years as long as the facility itself is well-managed and safe. But funding crises, equipment failure, mismanagement, mistakes, and accidents are a fact of life. In addition, natural disasters, war, and civil strife can all affect seed banks. Any of these factors can cause a seed bank to lose samples, resulting in the actual extinction of crop varieties and diversity. The loss of unique and valuable traits closes off options for the future development of agriculture—potentially robbing us of the resistance our food crops will need to ward off the next attack by pests and diseases, or of the heat tolerance required to cope with global warming, or of a nutritional quality that will improve diets.

In recent years, diversity has been lost in dozens of seed banks. And several seed banks have been utterly destroyed (Iraq, Afghanistan) or severely damaged (Philippines.)

The small team that conducted the feasibility study for the Seed Vault in 2004 quickly settled upon Svalbard as the best and perhaps only viable location for the facility, for a number of reasons:

- In Svalbard, one can take advantage of the permafrost, which offers natural freezing for the seeds, a key requirement for long-term conservation. Additional mechanical cooling down to -18° Celsius, the international standard, is easily accomplished.
- Svalbard is remote, and that remoteness provides security from human-related dangers. It is, however, still accessible. Seeds can easily be transported to and retrieved from Svalbard. The combination is unique.
- Military activity is prohibited in Svalbard under the terms of an International Treaty.[1]
- The political situation is stable. The local government is highly competent and helpful. The local community also is small and supportive.
- Infrastructure is excellent. Locally mined coal provides power generation. The area also has good communications links.
- The technical conditions at the site were virtually perfect. The location inside a mountain obviously increases security and provides unparalleled insulation properties. The area is geologically stable. Radiation levels inside the mountain are quite low. Humidity is relatively low. And it was possible to position the facility far above the point of any projected or possible sea level rise due to climate change.
- There was experience in storing seeds and managing underground sites in Svalbard. The Nordic countries have been doing so in a coal mine in Svalbard since 1984.
- Norway is a trusted country. It also is unusually "global" in its outlook, and generous when it comes to supporting positive international initiatives. Norway has no perceived conflict of interest in hosting the site.
- And finally, those involved in the conceptualizing of the project had close ties with and access to policy-makers in Norway, facilitating consideration of the proposal at the highest levels of government.

No other location in the world offered all of the above.

[1] Parties to the Treaty of Svalbard include: Afghanistan, Albania, Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Chile, China, Denmark, Dominican Republic, Egypt, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Italy, Japan, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Saudi Arabia, South Africa, Spain, Sweden, Switzerland, USA, United Kingdom, Venezuela.

A number of factors determined the precise location of the Seed Vault. Ideally, the Seed Vault needed to be near the village of Longyearbyen for ease of access and transport of seeds. It needed also to be near an existing road. Roads are expensive to build in Svalbard, and for environmental reasons one would wish to avoid building new roads. The site chosen necessitated construction only of a short access road off of an existing road. The site had to be away from coal seams which could present a risk of fire or explosion, and might be the target of future development. And it needed to be away from any cultural or historic relic. (A protected old mining entrance is nearby but sufficiently distant.)

Most obviously, the Seed Vault is located inside a mountain. The mountain is mainly composed of sandstone. The surface layer of rock is loose, the result of repeated freezing and thawing for millennia. Beyond this, the permafrost area begins and the rock is solid. The temperature at its coldest in the mountain is between minus 4 degrees Celsius and minus 6 degrees Celsius. This is where the actual vault rooms are situated. Past this, the temperature begins to rise again until, of course, one exits out the other side of the mountain. Thus, the vault rooms are in the coldest part of the mountain.

Even given worst-case scenarios for global warming, the vault rooms will remain naturally frozen for up to 200 years according to the Norwegian Meteorological Institute, and very cold and exceptionally well insulated for as far into the future as one can imagine. Under any scenario, therefore, the Seed Vault remains, in absolute and relative terms, the best possible location for providing secure and reliable conditions for seed storage. If refrigeration equipment fails, the facility will remain cold and the seeds frozen. There will be plenty of time to have the equipment repaired before any damage is done to the seeds. The Nordic Gene Bank’s safety backup collection in the coal mine is stored in slightly warmer conditions than will exist naturally without mechanical cooling in the Seed Vault. There has been no measurable decline in the viability of these seeds after more than 20 years.

The ideal placement of the vault rooms inside the mountain necessitated the construction of a long tunnel, some 125 meters into the mountain. Equipment used to build tunnels for highways was shipped in from mainland Norway for this purpose. The original design called for two vault rooms, contingent on the structural qualities that the workers found inside the mountain when tunneling began. The original plan envisaged a total storage capacity of 3 million seed samples. However, once inside the mountain, plans changed. Planners decided that a slight change in the dimension of the planned rooms and the addition of a third room would improve structural stability and strength, without appreciably increasing construction costs.

Each of the three vault rooms is approximately 27 meters long, 9.5 meters wide, and 5 meters high. Entrance is through a set of air-lock doors, which serve primarily to keep the cold air from escaping during the brief periods when people enter to deliver or retrieve seeds.

The addition of the third vault room increased storage capacity by 50 percent to 4.5 million samples. At this size, the Seed Vault has considerable excess capacity, and using current management guidelines, it is not likely to require expansion for hundreds or even thousands of years. If expansion ever becomes necessary, a new vault room could easily be tunneled out next to the existing rooms, or one of the existing rooms could be expanded.

There is a single entrance to the Seed Vault, through the doors of the portal building, a concrete wedge that protrudes from the mountain. This construction houses a 10 kilowatt (kW) compressor that keeps the seeds frozen to minus 18 degrees Celsius to minus 20 degrees Celsius, the optimal temperature range for maximum long-term storage. The compressor is powered by locally-generated electricity. During the initial cooling phase, an additional compressor was brought in—a much larger one (30 kW) –to cool vault room number 2, the middle of the three vault rooms. This vault will be used exclusively until it is full. During the cooling down process, cold air was pumped into vault 2, freezing the rock area surrounding it far below the natural permafrost conditions.

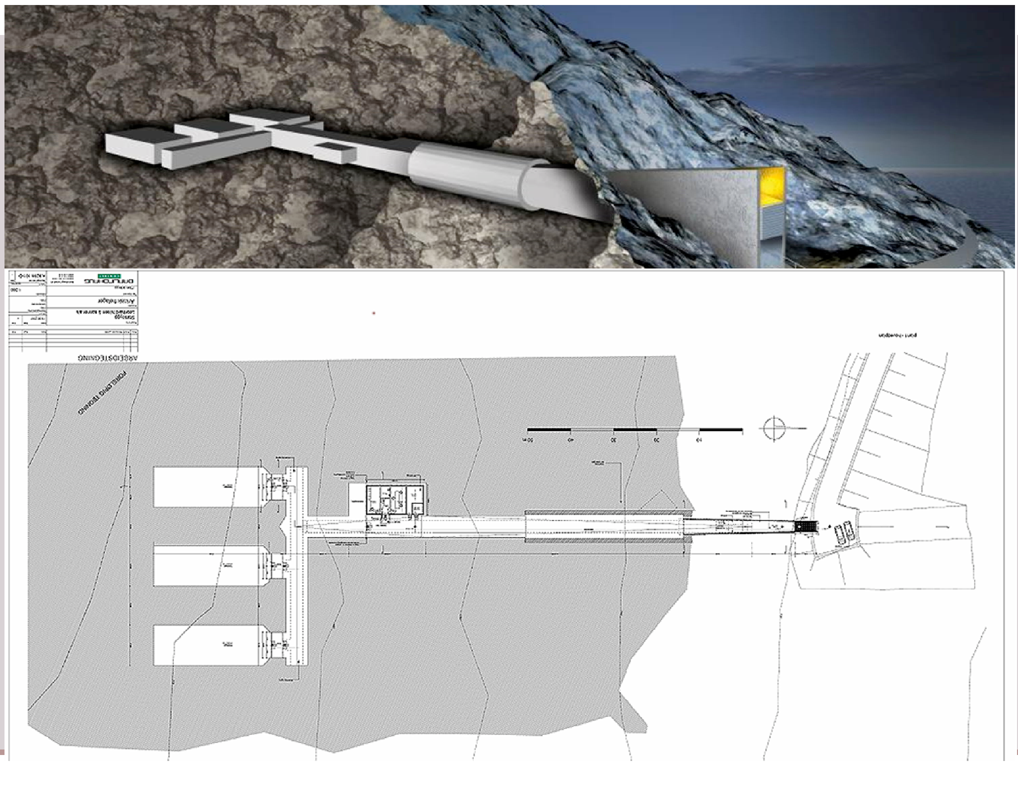
From the outside entrance into the portal building, one looks down a long and surprisingly large tunnel. As one walks along this gently downward sloping tunnel, one comes to several small rooms on the right side. One is an electrical room housing controls for the compressor and other equipment. One is a transformer room to which only the power company officials have access—this houses the equipment needed to transform the incoming electrical current down to 220 volts. And there is an office equipped with a computer with Internet access. The office can be heated on a temporary basis to provide comfortable working conditions for those that will log samples in and out of the Seed Vault.

Just beyond the office, the tunnel is walled off. Before getting into the vault area, one first needs to go through a sturdy door. This allows the entire area around the vault rooms to be very cold—even colder than natural permafrost conditions. It also prevents the escape of this very cold air, increasing efficiency, and serves as an additional security barrier.

In Norway, government-funded building projects typically include art. Indeed, projects exceeding a certain cost are required to do so. The art in the case of the Svalbard Global Seed Vault will be visible to all. As one faces the Seed Vault, one sees the portal building, a triangular concrete wedge or fin jutting from the mountain. On the upper part of the front wall above the front door of the facility and extending along the roof is a "light" designed by the Norwegian artist Dyveke Sanne and produced and executed by KORO, the official body for art in public spaces in Norway (www.koro.no). Using special metal, mirrors, and 200 fiber optic cables, Sanne has fashioned a beacon that will reflect the polar light and emit a muted glowing greenish/turquoise and white light in the dark periods at Svalbard. The piece was installed in January 2008 under difficult weather conditions.

The Seed Vault also has multiple security systems. First and foremost, its remote location offers a built-in layer of safety. But the system also has a series of locked doors; motion, fire, and smoke detectors; and alarms. Security officials also will monitor the site.

The Seed Vault also benefits from the fact that it is an unlikely target of any purposeful



hostility. Still, we know that bad things happen in this world, and one must be prepared.

Anyone seeking access to the seeds themselves will have to pass through four locked doors: the heavy steel entrance doors, a second door approximately 115 meters down the tunnel, and finally the two air-locked doors. Keys are coded to allow access to different levels of the facility. Not all keys will unlock all doors.

Electronic equipment will constantly monitor the temperat ure in the Seed Vault as well as gas levels (methane and CO2) and transmit data constantly via the internet to local authorities in Svalbard and to the Nordic Gene Bank. The Global Crop Diversity Trust will also have access to this stream of information.

At the end of the tunnel, a concave carving in the rock is designed to send any shock wave from any projectile causing an explosion back out of the tunnel, away from the vault rooms.

The vault rooms themselves are located more than 125 meters on a horizontal plane from the entrance and, vertically, are more than 150 meters below the surface of the top of the mountain. Boxes of seeds inside the rooms are scanned before entering the Seed Vault.

One sometimes hears the question: "Could the Seed Vault survive being hit with a nuclear bomb?" This, of course, is a highly unlikely scenario, and the glib answer is that it depends on how big the bomb is, of course. At this time there is no missile capable of penetrating to the depth of the seed vault. Even the "bunker buster" bombs are not currently able to reach to this depth with any substantial effect. However, bunker buster systems now under development if armed with a powerful nuclear bomb and if deployed directly at the Seed Vault, would send off shock waves that could damage or destroy the facility.

The management system for the Seed Vault was designed with the goal of ensuring the longevity of the seeds, minimizing risk, and minimizing cost. The planners and designers of the Seed Vault envisaged a structure and a management system that would almost operate by itself, with scant human intervention. And yet it is a managed facility. It is not a "time capsule" that is sealed and forgotten.

The collection housed in the Seed Vault will be assembled in an iterative fashion, beginning with the large international and national collections. Genebanks wishing to deposit samples after that will be instructed to send only those samples that are not already being conserved in the Seed Vault. Any sample stored in Svalbard should be available to all from the genebank that deposited it.

Storage in the Seed Vault is free. Genebanks are responsible for paying shipment charges to Svalbard, and for the costs of return shipment, if necessary. However, the Global Crop Diversity Trust is financing the preparation and shipment of seeds from developing countries and international agricultural research centers.

The Nordic Gene Bank will maintain a database of the seed samples going into the Seed Vault. Genebanks will be able to check this listing on-line to ascertain whether a particular sample is or is not already in the Seed Vault. A new global sample-level database being developed with Global Crop Diversity Trust funding will help with this process and provide the means by which plant breeders and researchers can search available information on the collections, and find and access the diversity they need.

The deposit of samples in Svalbard does not constitute a legal transfer of genetic resources. There is no transfer of ownership. Norway will not own the seeds. Neither will the Global Crop Diversity Trust nor the Nordic Gene Bank.

The Seed Vault functions like a safety deposit box at a bank. The bank owns the building and the vault, the depositor owns the contents of his or her box. In this case, Statsbygg, the Norwegian Directorate of Public Construction and Property (http://www.statsbygg.no/System/Topp-menyvalg/English/), owns the facility and the depositing genebanks own the seeds they send. Each depositor will sign a Deposit Agreement with the Nordic Gene Bank acting on behalf of Norway. The Agreement specifies that Norway does not claim ownership of the deposited samples and that ownership remains with the depositor who has the sole right of access to those materials in the Seed Vault. No one has access to someone else's seeds from the Seed Vault in Svalbard. Access to that diversity will be access to the other copy of the seed sample—the copy held by the depositing genebank. And it will, in most cases, be access in accordance with the terms and conditions of the International Treaty on Plant Genetic Resources for Food and Agriculture.

The seeds will be packaged in heat-sealed, laminated, moisture-proof foil packages. Such packets are routinely used for long-term storage of dried seeds in genebanks. The Global Crop Diversity Trust has worked with Barrier Foil (now Moore and Buckle Flexible Packaging) of the UK to design a new, more robust packet especially for the Seed Vault. This foil package is constructed of four laminated layers: a thick layer of aluminum foil as a moisture barrier and a cross-laminated, high-density polythene as a puncture-resistant barrier. When combined with two other layers of special proprietary plastics and bonded together with adhesive, it gives us the required characteristics while still being only 160 microns thick—just 50 percent thicker than a sheet of photocopy paper. Two sizes are used: 90 mm x 120 mm, and 130 mm x 260 mm. The Trust has purchased 300,000 of these packets for international centers and developing countries.

The packets will be stored inside boxes—plastic or sometimes heavy cardboard. Recycled polypropylene boxes supplied by the Trust to developing countries and international centers are 600 mm long, 400 mm wide, and 250 mm high. The Trust has purchased more than 1000 of these boxes for the Seed Vault. They are manufactured in France, weigh 3 kg each, and have a usable volume of 46 liters.

Typically 400 to 500 samples will fit in a box depending on the size of the seed. Individual samples will usually contain about 500 seeds. When the first vault room is filled with 1.5 million samples—about the number of distinct varieties we think exist—it will contain approximately 750 million seeds.

On opening day, we estimate that approximately 100 million seeds will be placed in the Seed Vault initially, weighing roughly 11 tons.

The boxes themselves are sealed. No one associated with the Seed Vault will open them. We refer to these as "black boxes" because the contents are not visible or available to those providing the cold storage. The boxes will, however, go through electronic X-ray screening at the airport as a security precaution.

Table 4. Predicted Longevity of Seeds of Selected Crops

Crop	Expected Longevity at 5% Moisture Content Stored at -20° C, in Years
Barley	2061
Chickpea	2613
Cowpea	5342
Lettuce	73
Maize	1125
Onion	413
Pea	9876
Pearl Millet	1718
Rice	1138
Sorghum	19890
Soybean	374
Sunflower	55
Wheat	1693

Reference: Pritchard, H.W. and Dickie, J.B. (2003) Predicting Seed Longevity: the use and abuse of seed viability equations. In Smith, Dickie, et al., Seed Conservation: turning science into practice. Royal Botanic Gardens, Kew, UK.

The long "life expectancy" of seeds stored in optimal conditions such as those in Svalbard leads some to assume that once a seed sample reaches the end of its days, all will be lost. But the Seed Vault is not a time capsule where one places seeds, walks away, and forgets about it. It is a backup system for functioning genebanks. Seed in working genebanks never reaches the thresholds given in the table above. Genebanks simply do not keep a sorghum sample for 20,000 years or even a lettuce sample for 73, because genebank seed stocks are drawn down long before that by breeders and researchers accessing the seeds. These "drawdowns" necessitate the production of fresh seed from the remaining seed in a sample.

In any case, most genebanks will monitor the viability of their seed stocks. When seeds begin to lose viability (with germination rates dropping below 85 percent of the original level), management protocols specify that some seeds from the sample should be taken out, planted, and new fresh seed harvested to replenish the genebank's sample of that variety. When this process takes place, genebanks using the Seed Vault have agreed that they will send a fresh new sample to Svalbard. Because the Seed Vault will offer conditions second to none, we know that seed samples stored there will not lose viability faster there than in the best of the traditional genebanks elsewhere. Thus, seed will be renewed regularly, and the Seed Vault will always have a good, healthy sample ready just in case it is needed.

Not all of the world's crop diversity destined for Svalbard will pass through the doors of the Seed Vault on opening day, February 26, 2008. Indeed, it will take some years to assemble a reasonably complete set. There are good reasons for this. Genebanks lack sufficient supplies of many samples to enable them to send an appropriate number of seeds to Svalbard at this time. Average sample sizes in Svalbard will be 500 seeds per sample. If a genebank does not have a thousand or more seeds, it may well wish to multiply its stocks to obtain more seed first. Additionally, genebanks typically operate on a schedule of regenerating, or refreshing, their seed samples. It would be illogical to send seeds that have started to lose viability and are scheduled to be refreshed in the near future. Better to wait and send fresh seed. Finally, most genebanks lack the land and staff to multiply all their seed stocks instantly. It will take some time to implement a rational safety duplication plan resulting in the complete duplication of all the diverse varieties of crops in Svalbard. We judge the wait to be worth the risk, as it will stock the Seed Vault with good, new, healthy seed in adequate per-sample quantities. Nevertheless, a significant portion of the world's diversity will be safely stored away in Svalbard in a few years. And a great start will be made on opening day.

Under the terms of a tripartite agreement (Norwegian Ministry of Agriculture and Food, Global Crop Diversity Trust, and Nordic Gene Bank), responsibility for the management of the Seed Vault lies with the Nordic Gene Bank, located in Alnarp, Sweden. Nordic Gene Bank staff will travel to Svalbard from Sweden as necessary and monitor the facility electronically (along with officials in Svalbard) in the interim. Deposit of seeds will be by advance arrangement.

Institutions Expected to Deposit Seeds on the Opening Day

- Centres of the Consultative Group on International Agricultural Research (CGIAR):
    - Africa Rice Center (WARDA), Benin
    - Centro Internacional de Agricultura Tropical (CIAT), Colombia
    - Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico
    - Centro Internacional de la Papa (CIP), Peru
    - International Center for Agricultural Research in the Dry Areas (ICARDA), Syria
    - International Institute of Tropical Agriculture (IITA), Nigeria
    - International Livestock Research Institute (ILRI), Ethiopia
    - International Rice Research Institute (IRRI), Philippines
    - World Agroforestry Centre (ICRAF), Kenya
- Centre for Genetic Resources (CGN), The Netherlands
- Institute of Agri-Biotechnology and Genetic Resources, Pakistan
- Institute of Plant Breeding, College of Agriculture, University of the Philippines Los Baños, Philippines
- Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Germany
- N.I. Vavilov Institute of Plant Industry, Russia
- National Genebank of Kenya, Kenya
- Nordic Gene Bank (NGB), Sweden
- Plant Gene Resources Canada, Canada
- Seed Savers Exchange, USA
- United States Department of Agriculture – Agricultural Research Service (USDA/ARS), National Center for Genetic Resources Preservation, USA
- World Vegetable Centre (AVRDC), Taiwan

Inside the Vault

The Seed Vault is intended to house seeds of crops associated with food and agriculture. These may be seeds of old obsolete varieties, of traditional varieties selected and grown by farmers (typically in developing countries), or the wild botanical relatives of cultivated crops.

In all, there may be as many as 2 million distinct samples of such crops being stored in seed banks today, though we think the true number is probably closer to 1.5 million. The Seed Vault offers protection for *diversity* without regard to whether we think that diversity might be useful or valuable in the future. As the conservationist Aldo Leopold once remarked, the first rule of successful tinkering is to save all the pieces.

Ideally, the Seed Vault will not be storing multiple copies of the same variety. Storing one is sufficient. Seed banks depositing samples in Svalbard will continue to keep one themselves, meaning that each distinct variety will be safeguarded in at least two different locations, Svalbard and somewhere else. Ideally, they should be kept in three places to maximize security and access and to minimize transactions involving the Seed Vault.

At this time, the Seed Vault will not be accepting samples of plants whose use is primarily pharmaceutically-related. Why? First, one has to prioritize and start with something. We decided to start with food crops. Second, few collections of pharmaceutical and similar crops exist and the Seed Vault is not institutionally prepared to engage in collecting from the wild. And third, an international legal framework exists for plant genetic resources for food and agriculture that makes it possible to manage the Seed Vault efficiently for the benefit of all. A similar framework facilitating cooperation and transfer of samples does not exist for medicinal species.

Similarly, the Seed Vault cannot store seed of other plants, such as the thousands of different types found in the tropical rain forests. Few collections of these plants' seeds exist in genebanks, and the Seed Vault is not in the position to care for and periodically grow these seeds to obtain fresh supplies when original deposits begin to lose viability in storage. Little is known about conserving seed of these kinds of species in seed banks. Before such seed could be efficiently conserved in Svalbard, traditional seed banks will have to get involved, perform necessary research, develop conservation protocols, commit to re-supplying seed when required, etc.

The Seed Vault will also house seeds of some of the native plants of Svalbard.

Many people are curious about whether genetically modified seeds (GM seeds) will be stored in Svalbard, and what, if any, dangers or advantages such storage might pose to other samples or to the environment. Certainly, any dangers that might exist are minimal at most. Seeds are stored at minus 18 degrees Celsius in sealed air-tight packages inside sealed boxes, behind multiple sets of locked doors, deep inside a mountain in the far northern reaches of the Arctic where there are no farms and no possibility that seeds of any agricultural crop could survive in the natural environment.

But the administration of the Seed Vault has decided against deciding which diversity is worthy of being conserved for future generations; that would be presumptuous and risky. Nevertheless, at this time, the Seed Vault will not be able to offer storage to GM varieties. Norwegian legislation, formulated prior to the discussions that led to the establishment of the Seed Vault, establishes strict conditions under which such seed can be imported and stored. The Seed Vault does not meet these conditions and thus importation under existing law would not be possible. It should be noted, however, that GMO varieties exist for only a few crops; most genebank collections were assembled before the advent of GMO technology; and most diversity can easily be represented in the varieties that will find a home in Svalbard. The Norwegian government has signaled that it will consider any recommendation made by the Seed Vault's International Advisory Council in regards to GMOs in the context of the Seed Vault's purpose to secure conservation for the world's crop diversity. In the meantime, both GMO opponents and proponents agree on the importance of the Seed Vault.

Some crops, such as banana, typically don't produce seed. And seed of other crops, such as coconut, cannot be conserved by drying and freezing. Thus, Svalbard cannot protect everything. The Global Crop Diversity Trust is working with genebanks to devise and improve ways for conserving diversity of such crops.

The Government of Norway funded construction of the Seed Vault at a cost of almost USD $9 million. The Government has signed a long-term contract with Statsbygg to provide on-going maintenance of the structure at a cost of approximately $100,000 a year. The Global Crop Diversity Trust will provide $125,000 to $150,000 annually for operation costs. The Trust is also initially allocating $500,000 to the task of assembling and shipping seeds to Svalbard from around the world.

The Trust is assembling an endowment fund to finance the conservation of crop diversity forever. Svalbard would be just one of the beneficiaries. Currently it accounts for less than 2 percent of the Trust's expenditures.

One last word of appreciation goes to the cooperating institutes and to their genebank staff. For months, many people worked long hours to prepare seed shipments. These individuals, along with farmers and plant breeders who have protected and nurtured crop diversity, are the real heroes of this story.

Table 5. List of Crops for Deposit in Svalbard Global Seed Vault
(from inventory lists as of 1 February 2008)

Crops for Deposit in SGSV			
Alfalfa	Chinese cabbage	Jackbean	Pea
Amaranth	Chinese kale	Jerusalem artichoke	Pear
Asparagus	Chives	Kale	Pearl millet
Azuki bean	Clover	Leek	Pepper
Bambara groundnut	Collards	Lentil	Pigeon pea
Barley	Coriander	Lettuce	Potato
Basil	Cowpea	Leucaena	Proso millet
Bean	Crambe	Lima bean	Soybean
Beet	Cranberry	Loofah	Spinach
Blackberry	Cress	Maize	Squash
Brassica	Cucumber	Marrow	Strawberry
Broccoli	Currant	Melon	Sunflower
Brussel sprouts	Eggplant	Mint	Sweet potato
Cabbage	Endive	Mizuna (brassica)	Tomatillo
Cajanus	Faba bean	Mung bean	Tomato
Calendula	Fenugreek	Mustard	Tree seed species
Cantaloupe	Finger millet	Oat	Trefoil
Caraway	Flax	Okra	Triticale
Carrot	Forages	Onion	Turnip
Cauliflower	Foxtail millet	Oregano	Water spinach
Celery	Grasspea (Lathyrus)	Pak choi (brassica)	Watermelon
Chickpea	Groundnut	Parsley	Wheat
Chicory	Hops	Pasture grasses	Wing bean

Looking Forward

The opening of the Svalbard Global Seed Vault marks a turning point toward ensuring that the crops that sustain us will not be lost. It follows millennia of haphazard forms of protecting crop diversity, and decades of catch-up preservation efforts to save a mind-boggling number of seed varieties. Now, other steps must follow if we are to secure this resource fully and reap all the benefits it contains.

While the Seed Vault is a testament to international cooperation, most actions taken to conserve diversity are surprisingly ad hoc and uncoordinated. Ad hoc efforts cannot be expected to produce a truly effective, efficient, and sustainable global system for conserving crop diversity and making it available. And yet, this is precisely what is needed to preserve the world's most valuable living resource: a rational global system with clear, scientifically-based priorities and goals, accountability, and sustainable funding. The mission of the Global Crop Diversity Trust is to work with countries and institutions to develop such a system, and ensure that it is adequately funded to perform its essential tasks.

Five steps need to take place immediately:

1. **Collection and Rescue**: A large amount of unique diversity still exists in farmers' fields, particularly in developing countries. This diversity is threatened—with displacement by new varieties; by development and urban expansion; and by climate change, which will alter the environments to which current varieties are adapted. Indeed, scientists speak of the creation of entirely novel environments and the possible extinction of a third or more of plant species. We should begin by identifying the diversity most at risk and by pinpointing collection sites that are likely to harbor the traits crops will need in the future: tolerance to temperature extremes and to drought, for example. The Trust is working with climate modelers and with experts in Geographic Information Systems (GIS) to formulate such priorities.

2. **Information and Information Systems**: New climates and ever-evolving pests and diseases put a high premium on identifying and understanding the diversity held in genebank collections. The Trust is initiating a program to research and screen genebank samples. A global information system, linking the world's genebanks, must be established to facilitate searches of genebank databases. Such a system is being spearheaded by Bioversity International with Trust support.

3. **Long-term Conservation**: We need to assemble a small network of world-class genebanks that collectively can ensure the long-term conservation of crop diversity and ensure that they can do so reliably—not 49 out of every 50 years, but 50 out of 50 years. The Trust's endowment, when complete, will ensure that support will be available for the Svalbard Global Seed Vault as well as this network of top genebanks.

4. **Cooperation**: Crop diversity is the product of a long history dating back thousands of years. It is also the product of the labor and genius of farmers and plant breeders, past and current. All countries are interdependent when it comes to the crop diversity that underpins their agricultural systems. We must, therefore, to cooperate in fashioning systems to conserve crop diversity, make it available to all, and share in the benefits it produces. The adoption of the International Treaty on Plant Genetic Resources for Food and Agriculture lays out the ground rules for such cooperation. But countries must do more than ratify it; they must implement it. If they do, it will be possible for the Trust to help them create a rational global system.

5. **Financing**: A modest endowment—under USD $300 million—would be sufficient to generate enough income annually to support the conservation of all unique crop diversity. The Trust is building such a fund. Along the way, commensurate with the size of its fund, the Trust is entering into long-term contracts with key institutions to ensure the conservation of the crop diversity, in perpetuity, crop-by-crop.

Resources

The three partners in the Svalbard Global Seed Vault:

Nordic Gene Bank
www.nordgen.org/sgsv/
The site for practical information regarding deposit of seeds, etc.

Norwegian Ministry of Agriculture and Food
www.seedvault.no
The Government's Web site for the Seed Vault.

Global Crop Diversity Trust
www.croptrust.org
Here you will find news about the Seed Vault as well as information about the larger effort to ensure the conservation and availability of crop diversity forever. Subscribe (free) to the Trust's periodic "thought pieces" on the topic of crop diversity at www.croptrust.org/main/topics.php

More internet resources:

International Treaty on Plant Genetic Resources for Food and Agriculture
www.planttreaty.org

FAO Commission on Genetic Resources for Food and Agriculture
www.fao.org/ag/cgrfa/

Bioversity International
www.bioversityinternational.org

Consultative Group on International Agricultural Research
www.cgiar.org

And for information about Svalbard:

The Governor of Svalbard
www.sysselmannen.svalbard.no/eng/

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Page 6	*Visual diversity in carrots* Credit: Global Crop Diversity Trust
Page 7	*Wheat.* Credit: Global Crop Diversity Trust
Page 10	*Ethiopian farmer.* Credit: Cary Fowler/Global Crop Diversity Trust
Page 11	*Research institution processing seeds*. Credit: ICARDA
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Page 18	*Projected artist rendering of Svalbard Global Seed Vault*. Credit: Global Crop Diversity Trust
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Page 19	*Aerial view of Svalbard Seed Vault under construction*. Credit: Cary Fowler/Global Crop Diversity Trust
Page 20	*Genebank preparing seeds for shipment to Svalbard*. Credit: IITA
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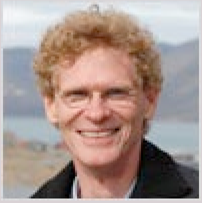
About the Author



Dr. Cary Fowler is Executive Director of the Global Crop Diversity Trust, which seeks to ensure the conservation and availability of crop diversity for food security worldwide. Dr. Fowler headed the international committee that assessed the feasibility of establishing a seed vault, and then developed its scientific and operational plan. He has been a central figure in virtually every aspect of its development from the beginning.

Prior to joining the Global Crop Diversity Trust, Dr. Fowler was Professor and Director of Research in the Department for International Environment & Development Studies at the Norwegian University of Life Sciences. He also was a Senior Advisor to the Director General of Bioversity International. In this latter role, he represented the Future Harvest Centres of the Consultative Group on International Agricultural Research (CGIAR) in negotiations on the International Treaty on Plant Genetic Resources.

Dr. Fowler's career in the conservation and use of crop diversity spans 30 years. He was Program Director for the National Sharecroppers Fund / Rural Advancement Fund, a US-based NGO engaged in plant genetic resources education and advocacy. In the 1990s, he headed the International Conference and Programme on Plant Genetic Resources at the Food and Agriculture Organization of the United Nations (FAO), which produced the UN's first ever global assessment of the state of the world's plant genetic resources. He drafted and supervised negotiations of FAO's Global Plan of Action for Plant Genetic Resources, adopted by 150 countries in 1996. That same year he served as Special Assistant to the Secretary General of the World Food Summit. He is a past-member of the National Plant Genetic Resources Board of the U.S. and the Board of Trustees of the International Maize and Wheat Improvement Center in Mexico.

He is the author of several books on the subject of plant genetic resources and more than 75 articles on the topic in agriculture, law, and development journals.