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The Svalbard Global Seed Vault – conserving plant genetic resources for European and global food security

Åsmund Asdal *

NordGen, Alnarp, Sweden

Abstract: The Svalbard Global Seed Vault is the largest safety backup of the world´s crop diversity. It offers safe storage for duplicates of seed samples conserved in genebanks worldwide. Since its opening in 2008, 123 institutes located in 87 different countries have deposited 1,331,458 seed samples of 6,297 crop and crop wild relative species in the Seed Vault. European institutes have very actively taken advantage of the opportunity to back up their genetic seed material. As of today, 38 institutes located in 30 different European countries have deposited 178,999 seed samples in the Seed Vault. Details about seed samples, depositors and species are publicly available through the Seed Portal website. The seed samples that are deposited in the Seed Vault remain the property of the depositing institute. The germplasm is at their disposal if they should need it, e.g. if the material in their home collections is damaged or inaccessible. The Seed Vault has already proved its value and importance for securing plant genetic resources when the International Center for Agricultural Research in the Dry Areas (ICARDA), formerly having its headquarters and genebank in Aleppo, Syria had to relocate their genebank activities, due to the Syrian Civil War. Deposited seeds withdrawn from the Seed Vault formed the basis for establishing new genebank functions at ICARDA units in Morocco and Lebanon.

Keywords: Svalbard Global Seed Vault, plant genetic resources, genebank, *ex situ* conservation

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Rationale and history

Plant genetic resources (PGR) are the raw material needed for the development of improved crop plant varieties, and therefore a precondition for securing future food supplies. Plant genetic material is conserved and made available for research and plant breeding by national, regional or international genebanks and other institutions and organizations holding plant and seed collections (Sanchez *et al*, 2023).

The first genebanks for seed conservation were established as early as in the 1920s, but most countries established their genebanks or genetic resource centres from the 1960s onwards. The Nordic Genebank (NGB) for plants was established in 1979 as a regional genebank for the five Nordic Countries (Denmark, Finland, Iceland, Norway and Sweden). NGB was merged with Nordic programmes for domestic animal genetic resources (AnGR) and forest genetic resources (FGR) in 2008, into the Nordic Genetic Resource Centre (NordGen) located at the Swedish Agricultural University in Alnarp Campus outside Malmö in Sweden.

Many genebanks are vulnerable to different types of natural and man-made disasters, war and conflicts or simply to lack of resources, and over the years valuable genetic material has been lost. Insurance policies are needed to ensure their protection (Asdal, 2021). The simplest and best way of securing this kind of material is to ensure the conservation of duplicates in storage facilities located in other geographical locations. The further away, the lower the risk for the same accident, natural disaster, political unrest etc. to occur both at the genebank and at the deposit location.

Considerations along these lines were the basis for the Nordic Genebank decision in 1984 to begin backing

*Corresponding author: Åsmund Asdal (asmund.asdal@nordgen.org)

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up the Nordic seed collection in an abandoned part of a coal mine in the Svalbard Islands (Figure 1), an Arctic archipelago administered by Norway, halfway between the mainland and the North Pole (Asdal (2021), Figure 2). The coal mine offered stable permafrost (i.e. permanently frozen ground) between -3 and -4°C that secured the freezing of seeds without any cooling equipment, energy supplies or even regular surveillance (Asdal, 2021). Over the years, around 13,000 seed samples of important Nordic agricultural and horticultural crops were placed in the coal mine and stayed there until the Seed Vault opened in 2008.

This low-tech and rather cheap solution gained extensive attention among genebanks and institutions committed to the conservation and use of PGR worldwide, FAO among these. The idea of storing backup copies of seed collections in a similar type of setting also from other national and international genebanks was launched quite soon and discussed and elaborated further through the 1990s (Qvenild, 2005).

When the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) came into force in 2004, the international framework for this kind of international cooperation became established and discussions about a global seed storage facility in Svalbard were revived. A report was commissioned by the Norwegian Ministry of Foreign Affairs to investigate the feasibility of establishing an international seed facility in Svalbard based on political, legal, technical and practical considerations (Fowler *et al*, 2004).

Based on the recommendation of this report, Norway presented the offer to build and manage a global seed vault in Svalbard at the FAO Commission on Genetic Resources for Food and Agriculture (CGRFA) meeting in Rome, Italy in 2004. The offer comprised secure black-box storage of backup seed samples of genebank collections conserved in optimal storage conditions at -18°C. Black-box conservation in this case implies that the deposited seed samples remain the property of the depositing genebank, the seed material is conserved in sealed boxes and the material can only be returned to the owner if needed.

After comprehensive international support, orally expressed already in the CGRFA meeting, the Seed Vault was funded and built by the Norwegian Government in 2007 (Asdal, 2021) (Figure 3). The broad support also materialized in the fact that many genebanks quite quickly began to prepare seeds for the opening event. Already at the Seed Vault opening on the 26 February 2008, 19 genebanks deposited 237,106 seed samples, which was a significant manifestation of the international commitment to increase the security of PGR and an acknowledgement of the role of the Svalbard Global Seed Vault.

The main objective of the Svalbard Global Seed Vault is to conserve security duplicates of unique seed samples that are conserved in regular genebanks. Over the years, the Seed Vault has also become a strong and iconic symbol of the importance of conserving PGR, and it is now actively used in public and media outreach to increase public awareness about the importance of PGR conservation and use. This is illustrated by the fact that the Seed Vault today is, even when the interior is closed to visitors, one of the top tourist destinations in Svalbard.

Building the Svalbard Global Seed Vault fits in a long-term Norwegian commitment to support international efforts and projects on conserving biological and genetic diversity. Svalbard is and will, despite severe climate change in the Arctic, also in the future be a cold place suitable for frozen storage for seeds. Together with good infrastructure and public services in Svalbard and international confidence in Norwegian management, Svalbard appears to be an ideal location for a facility like this.

Ownership and cooperation

The Svalbard Global Seed Vault is owned by Norway and the Norwegian Government guarantees its continuous long-term management and conservation of the seeds. Seed operations, i.e. anything related to the dispatching and depositing of the seeds, are managed in partnership between the Norwegian Ministry of Agriculture and Food, the Global Crop Diversity Trust and the Nordic Genetic Resource Centre (NordGen). Communication with current and potential depositor genebanks, seed deposit routines and logistics are taken care of by NordGen while the Crop Trust supports seed multiplication and shipment from genebanks in developing countries. The three partners cover the management costs with larger parts of the budget coming from the Ministry and Crop Trust.

The three partners work together on increasing awareness of the Svalbard Global Seed Vault and encouraging more genebanks to back up their genetic resources in Svalbard. Information is disseminated on different platforms, through websites and social media, by conferences and online lectures, through genebank visits and media interviews. Despite access inside the Seed Vault has been closed for all visitors due to security reasons since 2018, a broad diversity of visitors goes to Svalbard on the occasions of Seed Vault openings when seeds are brought into the Seed Vault, including genebank representatives, scientists, politicians, international organization officials, journalists and TV teams.

The Seed Vault operates in close connection with FAO and its CGRFA and ITPGRFA. Information about the Seed Vault and its offer to secure genetic resources from genebanks worldwide is regularly conveyed in meetings and side events in FAO bodies and ITPGRFA governing body meetings. The Seed Vault mission is reported and presented in documents and reports from these organizations. The ITPGRFA Benefit-Sharing Fund has supported several projects aiming at securing seed collections in the Vault.

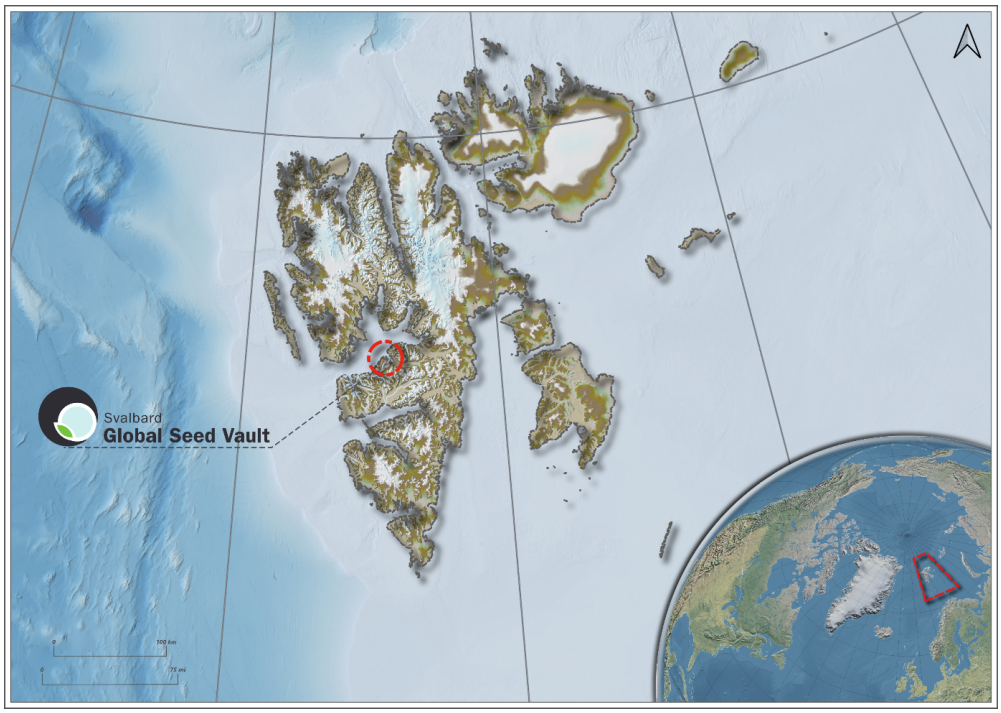

Figure 1. The location of the Global Seed Vault and the location of the Svalbard archipelago (map developed by Claudio Ballerini, using QGIS).

Figure 2. The history of conserving seeds in permafrost started in 1984, when backup samples of the Nordic Gene Bank seed collection were deposited in a steel container placed in an abandoned shaft of Cole Mine #3. The container is still in the mine, hosting some experimental seed samples while the backup collection has been moved to the Seed Vault. (Photo: NordGen)

Figure 3. The Svalbard Global Seed Vault was constructed in 2007 and opened in February 2008. It is located on the hillside of the Plateau Mountain above Longyearbyen airport, around 4km outside Longyearbyen town centre. (Photo: NordGen)

The facility

The Seed Vault consists of an outer so-called Portal Building, situated 130m above sea level, leading into an 80m-long tunnel ending in a large transverse hall with doors leading into three seed chambers. The total depth of the construction is about 130m, which includes the Portal Building, the tunnel, the transverse hall and the seed chambers, each 12m wide and 27m long. The seed chambers have between 40 and 60m of solid rock between the roof and the hillside surface (Figure 4). Natural permafrost in the ground provides between -3°C and -5°C. The seed chambers are artificially cooled down to -18°C, which is the recommended temperature for long-term conservation of seeds in genebanks (FAO, 2014).

During the first years of operation, melting water in the hillside in the summer seasons and rainfalls caused water intrusion in the entrance tunnel. Pumps were installed in the lower part of the tunnel to pump out the water. Heavy rainfall in October 2016 caused more water to enter the tunnel than ever before. Although the chambers containing the seeds were not affected by the water, the incident convinced the partners and the Norwegian Government of the need for a new watertight entrance tunnel. Knowledge about expected increased temperatures in Svalbard also contributed to the decision to construct an improved entrance tunnel. A new watertight tunnel was funded by the Norwegian Government and completed in 2019.

In the same project, a new building for housing technical equipment such as ventilation and new cooling machines was constructed, and a range of security measures and surveillance systems were installed. The renewed Seed Vault is now well-prepared for all kinds of threats including climate change and possible hostile actions. Warmer temperatures in the Arctic will not threaten the security of the seeds in the Seed Vault but will require some more electric power to cool down the interior of the Seed Vault.

Each of the three seed chambers in the Seed Vault has the capacity to store 1,5 million seed samples, which is approximately twice the number of unique samples that are currently maintained globally in one or more genebanks (FAO, 2010) (Figure 5). However, genebanks are expected to expand their seed collections through new collecting missions aimed at securing crop wild relatives from natural habitats and farmer material in regions that so far have not yet been fully covered. In addition, research and plant breeding programmes will create new genetic material, and older varieties that are replaced will need to be conserved. Nevertheless, the Svalbard Global Seed Vault will have the capacity to conserve duplicate samples of unique genebank accessions for several decades to come.

Over the years, the Seed Vault has probably become Norway's internationally most well-known building and, by that, contributed significantly to increased public awareness about the importance of PGR conservation and use. As one of the preconditions for storing seeds in the Seed Vault is that the safety-duplicated genetic material should be available for plant breeding and research from the depositing genebank, the Seed Vault

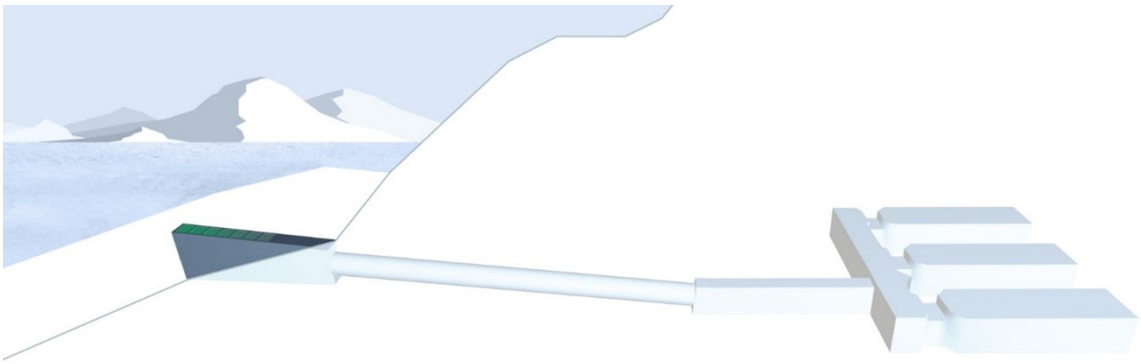

Figure 4. This model drawing shows the different parts of the Seed Vault, from the concrete Portal Building, visible from the outside, via the tunnel, transverse hall and three seed chambers. (Drawing: Norwegian Ministry of Agriculture and Food.)

Figure 5. Deposited seed samples are conserved in ordinary warehouse shelves in three seed chambers. The first chamber was filled up in 2020, and the second chamber was taken into use. The third chamber has not been taken into use yet. (Photo: Riccardo Gangale/The Norwegian Ministry of Agriculture and Food)

mission may also indirectly contribute to keeping genetic resources in the public domain.

Seed deposit management

The Svalbard Global Seed Vault offers a free-of-charge service to store duplicate samples of seeds that are conserved in genebanks worldwide. The Seed Vault is normally unstaffed, but NordGen organizes three so-called Seed Vault opening weeks each year to receive seed shipments for deposit in the Vault. Current and potential depositor genebanks are informed about the dates and encouraged to ship backup seed samples in advance of these occasions. On average, during the last few years around 12–15 genebanks have shipped seeds to the Seed Vault on each of these occasions.

The seed samples deposited in the Vault remain the property of the genebank. Only the owner genebank has access to the seeds and can require seed boxes to be returned if needed. All genebanks making their genetic resources available for research, breeding and education are eligible to conserve backup copies of their seed collections in the Seed Vault. In addition, conditions for depositing seeds in the Seed Vault are that the genetic resource should be under long-term storage in a genebank and backed up in a second suitable genebank at another location, making the Seed Vault the second security backup (NordGen, 2024).

Guidelines for depositing seeds in the Vault recommend that a safety duplicate should contain at least 500 viable seeds for outbreeders and heterogeneous accessions with high diversity and a minimum of 300 seeds for genetically uniform accessions. Seeds for long-term storage must be well-dried and packed in watertight aluminium pouches according to the FAO Genebank Standards (FAO, 2014). Seed pouches are packed in sealed

boxes or sent in packages that are put in standard plastic boxes upon arrival. Different box materials are accepted as long as they are robust enough to remain solid through the shipment process.

Genebanks should compile and submit an accession list of the seed material to be deposited 4–6 weeks ahead of the opening date and then ship the seeds, ensuring that the seed boxes or packages are received in Longyearbyen, Svalbard before the announced seed deposit event takes place. Before deploying seed boxes in the Seed Vault, all sealed seed boxes are X-rayed for any unwanted and potentially harmful items inside the box.

Seed boxes are sealed and not opened when conserved in the Seed Vault. The depositing genebank is responsible for monitoring the quality of the seeds over time, normally by performing germination tests on seed samples of the same yield that are conserved in their home genebanks. Depositors are also allowed to deposit boxes with test samples that can be returned if a genebank wants to test seeds that actually have been conserved in the Seed Vault for a shorter or longer time. When germination falls under the genebanks' own threshold, new seeds must be produced and sent to Svalbard.

Some genebanks have started to send newer samples of previously deposited accessions, coordinated with their plans for the multiplication of accessions for their own needs. When all accessions in a previously deposited box have been re-deposited, the whole box in question will be removed from the Seed Vault.

Seed Vault holdings

Between the opening in 2008 and November 2024, 123 institutes located in 87 different countries have deposited 1,331,458 seed samples of 6,297 crop and crop wild relative species in the Seed Vault (Figures 6 and 7).

Depositor genebank and institutes are International Agricultural Centres (IARCs), two regional genebanks (NordGen and SPGRC in Southern Africa), many national genebanks and universities, a few NGOs and so far, one private company. Information about all depositing institutes is publicly available on the Seed Portal search page https://seedvault.nordgen.org/Search. About two-thirds of deposited samples are owned by IARCs and one-third by national genebanks including university collections (Figure 8).

As most genebanks conserve seeds originating from many countries, there are seeds originating from 229 different countries and territories in the Seed Vault. As genebanks tend to keep the original country name as the country of origin in their databases – even when countries split, merge or change names – former countries are also included in this large number.

European depositing institutes are mainly national genebanks of different sizes and with different responsibilities regarding crop conservation. Some countries have one centralized seed genebank while others have a more decentralized genebank system.

As of November 2024, 193,660 seed samples of 1,914 different species originating from 53 countries and territories in Europe were deposited in the Seed Vault. Thirty-eight (38) institutes/genebanks located in 30 different European countries have deposited 178,999 seed samples in the Seed Vault.

The Seed Portal database

As mentioned, information about seed samples conserved in the Seed Vault is saved in a specially developed and designed database called the Seed Portal. Genebanks provide accession lists with some basic data about all seed samples they want to deposit before each Seed Vault opening occasion. A template has been developed for this purpose, requiring information about accession number, scientific species name, country of origin, year of regeneration and number of seeds for each sample. Accession lists are uploaded to the database, and a validation process detects typos, errors and invalid information. Basic data is publicly available at the Seed Portal website https://seedvault.nordgen.org/.

The first and only withdrawal of seeds

The Seed Vault has already proven its value and importance for securing PGR when the International Center for Agricultural Research in the Dry Areas (ICARDA), formerly having its headquarters and genebank in Aleppo, Syria had to relocate its genebank activities, due to the Syrian Civil War. Seeds deposited from Aleppo between 2008 and 2014 were withdrawn from the Seed Vault in 2015, 2017 and 2019 and formed the basis for establishing new genebank functions at ICARDA units in Morocco and Lebanon (Westengen *et al*, 2020).

Concluding remarks

The Svalbard Global Seed Vault is welcoming all genebanks to deposit backup samples of the collection in this very safe place in the Arctic, and the ultimate goal is that all unique plant genetic material of orthodox-seeded species conserved in genebanks is secured and copied in the Seed Vault. In a troubled world, genebanks should implement safety measures for securing their genetic resources and conserving samples in more than one place is an easy solution.

The ICARDA case illustrated that genebanks in relatively stable countries, which was the common assumption for Syria up to the Arabic Spring, should ensure that backup samples are saved at one or more other locations. In addition, natural disasters and lack of resources can cause the loss of seeds and genetic resources in genebanks. The ICARDA case also showed that the concept of the Seed Vault set up for conservation and withdrawals of duplicate seed samples works well and meets the need for extra security for PGR. However, like any other insurance policy, the hope is that no

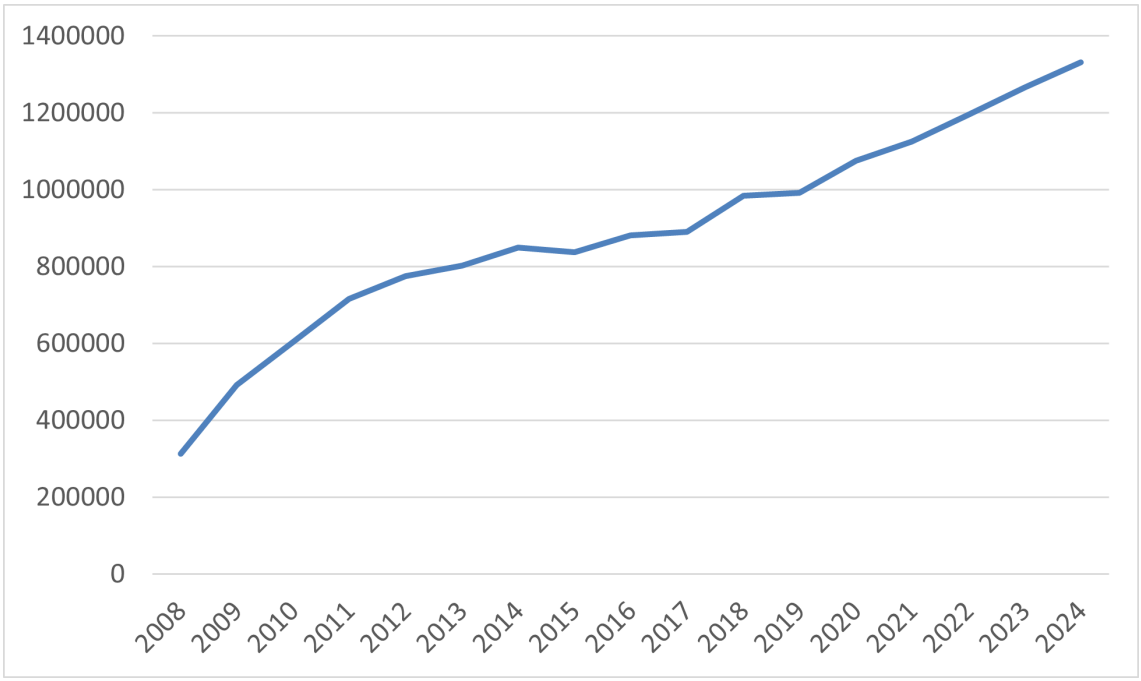

Figure 6. Graph showing the increase of Seed Vault holdings year by year from the opening in 2008 until the end of 2024. ICARDA withdrawals took place in 2015, 2017 and 2019, explaining a reduction or low increase in conserved numbers these years.

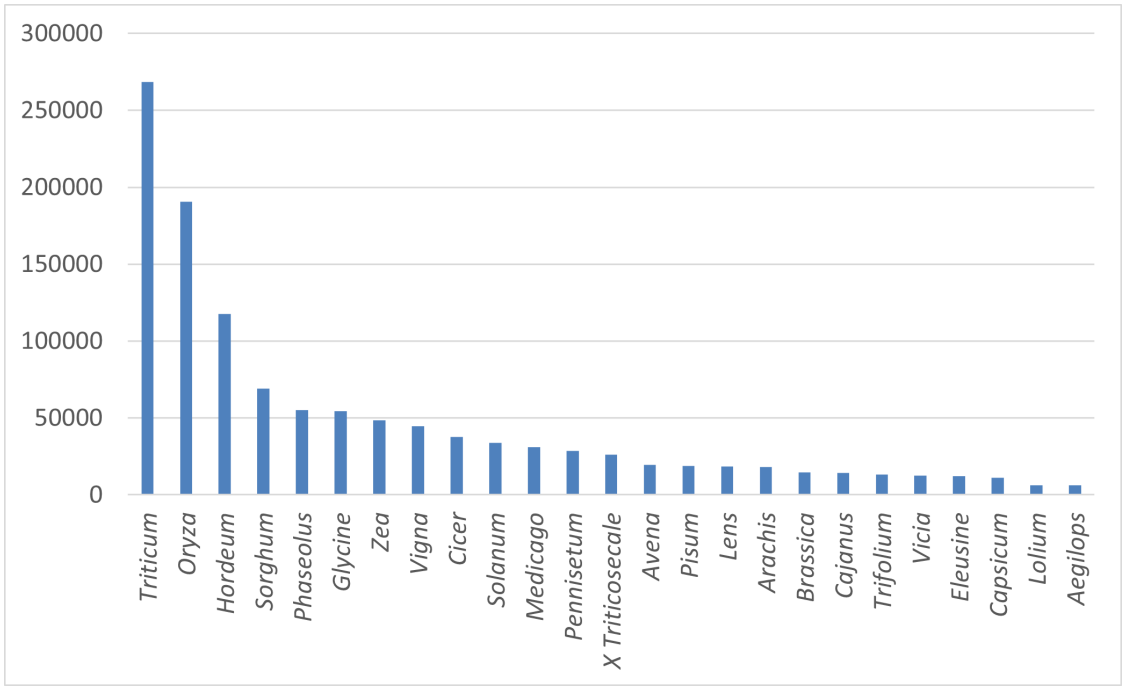

Figure 7. By the end of 2024, seed samples belonging to 6,297 species were conserved in the Svalbard Global Seed Vault. The graph shows the 25 genera having the highest numbers of samples conserved in the Seed Vault. Three genera are represented with more than 100,000 samples; *Triticum* (wheat): 268,353 samples, *Oryza* (rice): 190,758 samples and *Hordeum* (barley): 117,551 samples.

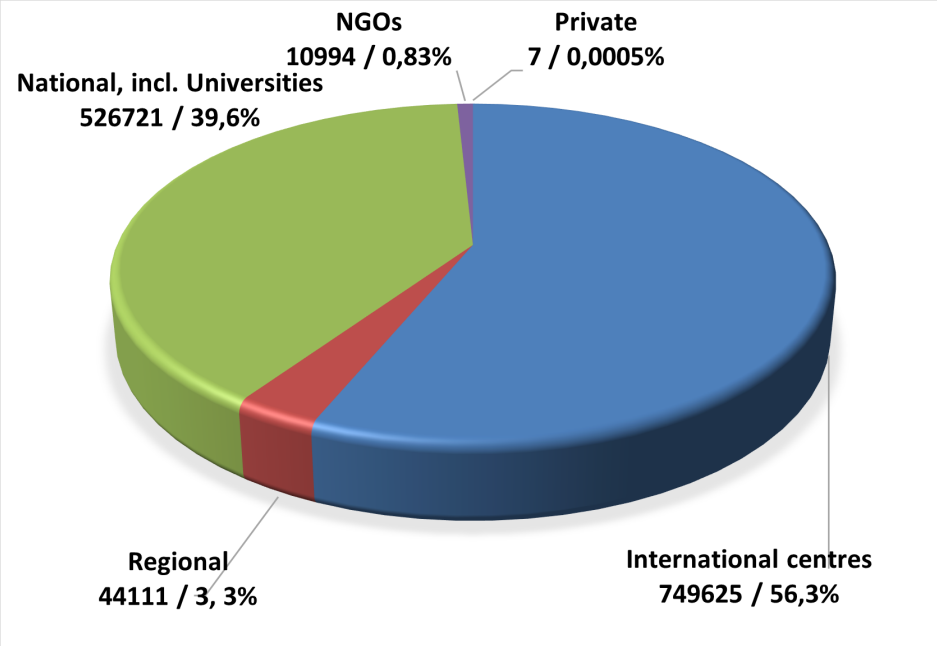

Figure 8. Diagram showing proportions of seed samples deposited by five different categories of genebanks and institutes.

further seed withdrawals from the Seed Vault will be needed.

Luckily, the 17-year story of the Seed Vault shows that many genebanks, along with international organizations and partners, acknowledge both the need for security measures for their genetic resources and appreciate the option provided by the Seed Vault. It is evident that the Seed Vault enjoys a high level of confidence among genebanks, ministries, scientists and other stakeholders. From the Seed Vault partners' point of view, it is highly appreciated that the number of genebanks that deposit their valuable genetic material in the Seed Vault is increasing year by year. It is also very satisfying to observe that the global support of the Seed Vault mission is quite unanimous, also in the media. Positive media coverage has undoubtedly contributed to increased public awareness about the importance of genetic resources and encouraged new genebanks to make plans for depositing seeds in the Seed Vault.

It is also inspiring to see that, in a world marked by conflicts, securing PGR in the Seed Vault is still an international effort where countries in different parts of the world cooperate despite disagreements in other fields.

The author of this article hopes that the Seed Vault mission can inspire and pave the way for peaceful international cooperation also in other sectors.

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Conflict of interest statement

The author declares that there are no conflicts of interest

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