



# *Ex situ* conservation of plant genetic resources in Europe – A journey through history, mission, challenges and future opportunities

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**Abstract:** The Special Issue entitled: ‘*Ex situ* conservation of plant genetic resources in Europe – A journey through history, mission, challenges and future opportunities’ presents 16 original articles, including 11 genebank reports from 7 European countries (Belgium, France, Germany, Hungary, Italy, Norway and Russia) and 5 review and position papers presenting relevant concepts to improve plant genetic resources (PGR) conservation and access. They provide an overview of PGR *ex situ* conservation in Europe, and reflect on the history and future directions of the collections. Important topics in PGR conservation and use are explored, including quality management systems for genebanks, the role of community seedbanks, the importance of collaborative research projects and national and international research infrastructures for PGR, and the integration of *in situ* and *ex situ* PGR conservation. From this article collection, the key importance of genebanks clearly emerges – not only in the long-term conservation of plant biodiversity but also in supporting and enabling plant breeding, research in plant biology and *in situ* conservation initiatives, highlighting important topics that should be prioritized for the efficiency and continuous improvement of PGR conservation activities. This article collection sparks discussions on future directions of *ex situ* plant conservation to further increase the impact of genebanks and their contributions to sustainable development.

**Keywords:** agricultural biodiversity, crop diversity, genebanks, germplasm banks, plant conservation

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## Introduction

Human societies have created, organized and conserved living collections of plant species since ancient times, in all areas of the world and for multiple reasons (Granziera, 2001). Since the end of the 19th century, researchers have conceptualized and highlighted the importance of the conservation and availability of plant genetic resources (PGR) for crop breeding and research, especially of landraces and crop wild relatives (CWR) (Plucknett et al., 1987). The modern concept of a genebank – a facility for the long-term *ex situ* conservation of reproductive samples of PGR acces-

sible for breeding and research purposes – was first realized at the beginning of the 20th century at what is now the N. I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR) in Saint Petersburg, which pioneered the collection, identification and description of the diversity of cultivated plants (Loskutov, 1999; Loskutov et al., 2025). Genebanks have since been established in many countries to preserve and keep available PGR and prevent the loss of wild plant populations and landraces due to substitution with modern high-yielding varieties (Lehmann, 1981). In Europe, one of the earliest genebanks was established in Gatersleben, then East Germany, after World War II, and subsequently became the German genebank after reunification in 1990. Other collections were established in several countries of Eastern Europe in the 1950s, including Bulgaria, Czechoslo-

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vakia, Hungary and Poland. Investments in national collections in Western Europe came later, after awareness was raised by the Food and Agriculture Organization of the UN (FAO) and technical conferences held in the 1960s, alerting about the risks of genetic erosion (i.e. “the loss of genetic diversity and variation in a crop”, van de Wouw et al. (2010)) due to displacements of old varieties by modern ones (Pistorius, 1997). The genebank of the Federal Republic of Germany in Braunschweig started operations in 1971, the Italian genebank in Bari in 1974, the Nordic genebank of the five Nordic countries in Lund, Sweden, in 1979 and the Dutch genebank in Wageningen in 1985. Many countries did not establish centralized genebanks, but their collections were created by universities as well as public and private research institutes. The splitting and sprouting of nations due to political changes after 1989, and the concept of sovereignty over genetic resources introduced by the Convention on Biological Diversity in 1992 (UNEP, 1992), opened the way to the expansion of conservation institutions. A large diversity of historical backgrounds and foundational motivations has given rise to a wide number (around 400) of institutes conserving PGR listed in the European Search Catalogue for Plant Genetic Resources (EURISCO, <http://eurisco.ecpgr.org>), summing up to more than 2 million accessions of PGR currently conserved *ex situ* in Europe. These accessions account for half of the total PGR accessions listed in the global Genesys database (Genesys PGR, [www.genesys-pgr.org](http://www.genesys-pgr.org)) and about one-third of all PGR accessions actively conserved in genebanks globally (FAO, 2025). These *ex situ* collections vary in their missions, expertise, financial sustainability, legal arrangements, size of collections, conservation and distribution methods, data information and quality management systems.

The *ex situ* conservation of PGR in genebanks is currently considered the most effective strategy to avoid losses in plant diversity and enhance the availability of these resources (Davies and Allender, 2017). This is particularly relevant considering that PGR represent a fundamental asset to widen and diversify the genetic basis of modern crop cultivars and provide useful traits for breeding in the current scenario of climate change and with the need to minimize negative impacts of agricultural production on natural ecosystems (McCouch et al., 2013; Pixley et al., 2023). Moreover, genebanks conserve and keep available landraces, old cultivars and neglected crops that are being rediscovered, after decades of genetic erosion in several European areas (see e.g. Hammer et al. (1996)), often linked with traditional foods and products and offering new opportunities for farmers and food industries (see e.g. Helicke (2024)).

Fostering collaboration among genebanks in different countries and involving different stakeholders can be an important strategy to strengthen the conservation and use of PGR (Engels et al., 2024). In the European scenario, the European Cooperative Programme for Plant Genetic Resources (ECPGR) is a collaborative

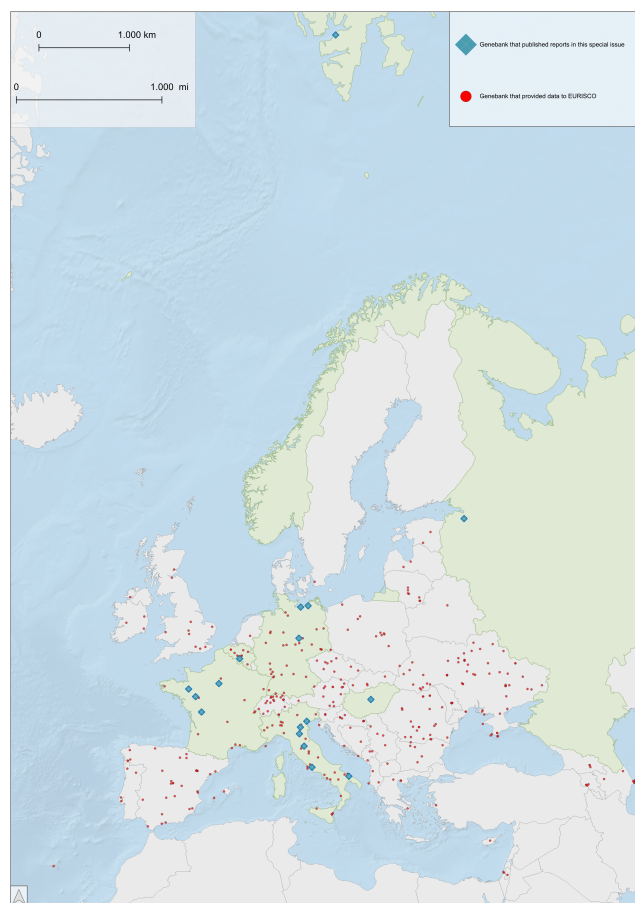
programme, active since 1980, among most European countries working together on multiple initiatives aimed at ensuring the long-term conservation and utilization of PGR in Europe. ECPGR recently published the *Plant Genetic Resources Strategy for Europe* (ECPGR, 2021). This document highlights gaps and necessary actions that should be addressed in the coming decade to ensure long-term PGR availability through their sustainable use and conservation. Consolidating and sustaining *ex situ* conservation is a priority action within the strategy, with several important targets identified that should be achieved by 2030.

In this context, this *Genetic Resources* Special Issue aimed at providing the opportunity to disclose, at a so far unpublished level of detail, a comprehensive overview of the history, mode of operation, strengths and weaknesses of some exemplary European institutions conserving plant germplasm as well as related mechanisms influencing their operation. Most of these data and observations are of high relevance for the PGR community, yet they are often difficult to publish in regular research articles or remain scattered across various publications, often in national languages. This collection not only showcases examples of successful initiatives but also serves as a valuable resource for policymakers, helping them to understand the state of the art in view of identifying opportunities for better cooperation and sharing of responsibilities.

## Content of the Special Issue

This Special Issue is composed of 16 original articles in addition to this Editorial, grouped into two main categories: (1) reports from genebanks describing their history, composition of the collections, key activities and future perspectives, and (2) review and position papers on emerging topics aimed at enhancing the conservation and sustainable use of plant diversity in Europe.

Eleven genebank reports from seven European countries are presented in this issue, namely: Belgium (Dumont et al., 2025), France (Esnault et al., 2025; Feugey et al., 2025; Ricou et al., 2025; Sampoux et al., 2025), Germany (Weise et al., 2025), Hungary (Ay et al., 2025), Italy (Alberti et al., 2025; Palombi et al., 2025), Norway (Asdal, 2025) and Russia (Loskutov et al., 2025). These reports are just a snapshot of the more than 400 *ex situ* collections registered in EURISCO (Figure 1). However, they cover all the main *ex situ* conservation techniques for plant germplasm (long- and medium-term orthodox seed storage, *in vitro* conservation, cryopreservation and field conservation, see FAO (2014)) and vary significantly in terms of number of accessions and plant species conserved as well as management practices (covering multi-species as well as crop- and species-specific collections). While most of the genebank reports in this issue deal with the conservation of PGR for food and agriculture, reports on other collections are also included (i.e. the Versailles *Arabidopsis* Stock Centre, collections of ornamental species and non-food industrial crops, the Pannonian Seed Bank as a con-



**Figure 1.** Locations of European genebanks contributing reports to this special issue. In red dots, the location of all institutions providing data to EURISCO (extracted from FAO WIEWS). Blue diamonds indicate the locations of the eleven institutions that published genebank reports in the Special Issue (some collections are conserved in different sites). The seven countries where these contributing genebanks are located are highlighted in green.

servation seedbank for wild species), and the Svalbard Seed Vault (Norway), the largest global seed collection of safety duplicates of crop genebank accessions.

Review and position papers offer a view on important topics for PGR conservation and use: quality management systems for genebanks (van Hintum and Wijnker, 2024), an overview of community seedbanks in Europe (Bocci et al., 2025), the importance of collaborative research projects and national and international research infrastructures to promote PGR conservation and use (Bergheaud et al., 2025; Goritschnig et al., 2025), and the integration between *in situ* and *ex situ* conservation of PGR (Maxted et al., 2025).

### Key messages

This Special Issue provides an overview of the diversity and complexity of *ex situ* conservation activities of plant diversity across Europe and on emerging topics to enhance the long-term conservation and use of PGR. The presented genebanks started assembling their PGR collections during the 20th century, particularly after

the 1950s. Collecting activities and the acquisition of new accessions are still ongoing, focusing especially on CWR, landraces and crop species that have often been neglected and are now being re-evaluated by research and breeding, promising adaptation to changing environmental conditions. Most genebanks today focus on improving the documentation, characterization, evaluation, access and use of conserved accessions and their associated data.

The genebank reports highlight the diverse functions that these institutions have within their national PGR conservation programmes and seed systems. The distribution activities of conserved samples across the years highlighted the importance of these genebank collections for research and breeding, for both the private and the public sectors. Genebank collections are fundamental sources of useful agronomic and stress tolerance traits for plant breeding and also provide plant germplasm material for hobby growers, repatriation and rematriation activities (Ocampo-Giraldo et al., 2020). Genebanks are also important to support the registration of newly selected or conservation varieties and to conserve and keep available old cultivars formerly registered in national variety lists. They serve as central nodes in networks and collaborative programmes, including private and public institutions and on-farm networks, aiming at enhancing PGR conservation and use. Genebanks are often active in outreach activities, raising awareness about the importance of agricultural biodiversity and its long-term conservation, while also promoting the use of PGR.

Most genebanks are open to, and actively engage in, international collaborations for research and exchange of genetic resources. However, the opportunity to evolve towards a more integrated system for the conservation and management of genetic resources at the regional level is rarely acknowledged as a shared goal. Evidently, the benefits that could result from shared management and use of resources – such as economy of scale, reduction of redundancies and gaps, and integration of expertise – are not immediately recognized at the local level. This is in line with the challenges faced by initiatives like AEGIS (European Genebank Integration System) in gaining traction (van Hintum et al., 2021).

In the framework of this Special Issue, important topics emerged that should be considered priority actions for the continuous improvement of PGR conservation activities in Europe:

- Fully implement **quality management systems** for genebanks, including the creation of a certification agency specialized in genebank activities to continuously improve the efficiency, reliability and transparency of all genebank operations.
- Establish **safety duplicates**, not only for orthodox seed accessions but also *in vitro*, cryo and field collections. This is an important step to reduce the risk of losing these priceless resources.
- Coordinate and integrate *in situ* and *ex situ* **conservation strategies**, acknowledging the role

of community seedbanks and on-farm conservation programmes. This integration will foster a dynamic management of PGR to ensure that the highest degree of plant genetic diversity is conserved and accessible to users at all times.

- Support ongoing **multi-omics characterization and evaluation** of conserved accessions. This will help refocus conservation efforts, identify collection gaps and allow the mining of collections for useful traits.
- Improve **data management** and accessibility of accession data, integrating passport data with novel multi-omics characterization and evaluation data collected during routine regenerations and as part of collaborative research projects. Better documentation of PGR including CWR and landraces will increase their value and therefore their use for research and breeding.
- Test and employ new technologies to enhance **automation and digitization** of routine processes in the management of collections to reduce errors and increase data quality.
- Establish national and **pan-European research infrastructures** that can coordinate conservation activities and streamline scientific services and research on PGR conservation and use. Improved pan-European coordination will help align the diverse and often heterogeneous PGR conservation activities, improving financial and operational efficiency and access to services.

Achieving these ambitious targets will improve the long-term conservation and accessibility of our priceless natural resources, which are pivotal to face present and future challenges related to food security, environmental sustainability and the implementation of nature-based solutions.

Overall, the tangible and invaluable contribution of genebanks to the long-term conservation of, and access to, plant diversity clearly emerged from this article collection. Furthermore, as the importance of PGR in breeding continues to grow and with it the increasing volume of PGR-related data, the scope of genebanks is widening to becoming bio-digital genetic resources centres (Maxted et al., 2025; Mascher et al., 2019). The genebank reports underline the value of documenting and sharing the history of genebanks with the broadest community to inform collections' management and establish future priorities. We encourage more genetic resources centres to share the fascinating history of why and how their collections were assembled, how their conservation and research methodologies have evolved and reflect on challenges encountered over the years and their corrective actions. This Special Issue can also be a useful source for young professionals interested in PGR to obtain an overview of genebanking in Europe and its future goals. Finally, we hope that initiatives such as this article collection can spark discussions on the future directions of *ex situ* plant conservation to further

increase the impact of genebanks and their contribution to sustainable development.

### Authors' contributions

FG drafted the paper, all the authors contributed to the writing, revised and approved the final version.

### Conflict of interest statement

The authors declare that they have no competing interests.

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