

INNOVATIVE TECHNIQUES FOR MONITORING AND EFFICIENT MANAGEMENT OF THE BULGARIAN GENE BANK

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Abstract

Every country is responsible for preserving its gene pool as a national capital. The genebank, located in Sadovo, is the main center for the long-term conservation of the plant diversity of Bulgaria. The research focuses on the development and implementation of innovative technologies for the management and storage of plant genetic resources. The main goal is to optimize the quality and efficiency of the processes in the National Genebank by intelligent systems and sensor networks to facilitate the monitoring of the accessions. The component for notification of control tests of the seeds and an interface for monitoring the chambers, as well as algorithms for intelligent search in ontologies are implementing. The importation of evaluation seed data from external devices is answering the need of digitalization of the genebank. The results have a significant scientific and public contribution leading the increase of the functionality and security of the genebank fund. The IS-PGR-SADOVO project supports the establishment of the quality standard for ex situ storage, in accordance with the Operational Guide for the Bulgarian Genebank, approved by the ECPGR Management Committee (2023).

Key words: seed accession, genebank, long-term conservation, innovation, digitalization.

INTRODUCTION

Plant genetic resources for food and agriculture are critically important for the sustainable food production in conditions of an ever-growing population and climate change (ITPGRFA, 2009). An important step in this direction is increasing the adaptability and productivity of crops in conditions of stress and reduced inputs, while ensuring sustainable development and protection of natural resources (Pilling et al., 2020). Each country is responsible for preserving its gene pool as a national treasure – a resource with biological and economical value, initial material for creation of new varieties that meet the requirements of current and future generations (Mattana et al., 2021). Conservation and documentation of genetic diversity goes beyond the mere storage of species and accessions, as it preserves traditional practices and cultures, including the

varieties of local communities. These people are the stewards of the world's crop biodiversity (Arnaudova et al., 2015).

One of the main priorities until 2030 at the European level is the guarantee of *open access* to the genebank funds for all users (ECPGR, 2021). *Ex situ* collections are the basis of bioeconomy and agri-food chain in conditions of climate change. The report of FAO (2025), based on information provided by 128 countries and several international research centres, highlights that losses in plant diversity continue, but there is progress in its conservation, unfortunately the deep gaps in digitalization of the world's *ex situ* collections are alarming. To increase efficiency of preservation of *ex situ* collections it is recommended to implement innovative technologies for documentation of tests for viability and quality of seeds in the process of storage, intelligent monitoring and control of

risk in chambers for guaranteed conservation that improve the genebank operations and the management system (Ay et al., 2024; Hintum and Wijker, 2024).

Many authors published results that reveal the broad potential of leverage new technologies in genomics and phenotyping to improve the utilization of conserved diversity (Arend et al., 2022; Anglin et al., 2025). Establishing of a "digital genebank" is an innovative approach that aims to decipher the genetic composition of stored collections, which is a prerequisite for solving a huge number of problems related to increasing the resilience to pests and diseases and adaptability to environmental changes of the new varieties (Kim et al., 2023).

Appropriate example is HortDB V1.0 – a genomic database of horticultural plants, providing bioinformatic information for researchers and crop breeders. All data and tools are with open access (Li et al., 2024).

A common priority for each of the National Genebanks is the expanding the scope of intelligent systems in the process of management, preservation and use of plant diversity (Mendel et al., 2019).

At IPGR - Sadovo is situated the National Seed Genebank of Bulgaria and the Institute coordinates all activities and represents the country in the European program on plant genetic resources (ECPGR).

The aim of the study is to analyse the available passport information of the Bulgarian Genebank collection and to present the methodological process for integration of innovative techniques for monitoring and efficient management of the conservation process.

MATERIALS AND METHODS

The Information Centre for Plant Genetic Resources at IPGR - Sadovo was created in 1982. It was completely renovated in the period 2019-2023 when also the National GeneBank Information System for plant genetic resources was established (Doychev et al., 2020; Velcheva et al., 2022). The Information Centre works according to the international standard for documentation of FAO/Bioversity (2017) for *ex situ/on farm* conservation of plant genetic resources and FAO/Bioversity (2022)

for *in situ* preservation of crop wild relatives. It is following the priorities for *open access* to the genebank collections in Europe, for available food plants databases as a bioresource for crop breeding and agriculture, and for maintaining a global system for free germplasm exchange between all users (French, 2018; Brink and Hintum, 2020; ECPGR, 2021).

The electronic database of Bulgarian Genebank contains the following passport information: taxonomic description, catalogue number, date of acquisition, country of origin, donor of the sample, collection site, ecology-geographical characterization, biological status, type of storage: long-term (base collection), medium-term (exchange collection), short-term (working collection), *in vitro*, cryo-conservation, field collection, botanical garden and agroecological data for *in situ* preservation of crop wild relatives. The National Seed Genebank in Sadovo represents Bulgaria in the European electronic catalogue on plant genetic resources EURISCO (<http://eurisco.ecpgr.org/>). The enrichment, storage, characterization and evaluation, reproduction and multiplication of the genebank collections are a result of hard work of the crop curators, conservation and documentation specialists from the Department "Plant Genetic Resources".

The medium-term collection is stored at temperature from 0 to +6°C for a period of up to 10 years. 45,000 seed accessions are maintained in the base collection under long-term storage conditions with low moisture contents (5±2%) in three laminated aluminium foil packets at -18°C. Seed viability is detected on the basis of germination rate. The germination tests are conducted at regular intervals: before the storage in the genebank, and periodically every 10 years (for specific crops – every 5 years). The moisture content of seed accessions, both before and after the time of storage, is determined. Genebank Standards for Plant Genetic Resources for Food and Agriculture is followed (FAO, 2013).

During the period 2024-2027, according to the IS-PGR-SADOVO project, financed by the Bulgarian National Science Fund of the Ministry of Education and Science, intelligent techniques and sensor network to support and automatizing all the processes related to the management and monitoring of the national

plant gene pool conserved at IPGR - Sadovo started to be developed. The component for notification of control seed germination tests and an interface for monitoring the chambers, as well as algorithms for intelligent search in ontologies are implementing. The importation of biometrics data of evaluated seed samples from external devices is planned to be digitalized.

The IS-PGR-SADOVO project supports the establishment of quality standard for *ex situ* storage, in accordance with the Operational Guide for the Bulgarian Genebank, approved by the ECPGR Management Committee (ECPGR, 2023) and the European research cooperation on plant genetic resources conservation and use (Goritschnig et al., 2025).

RESULTS AND DISCUSSIONS

Data management practices in Bulgarian genebank vary widely, reflecting the different methodologies, and progress in the technological infrastructures. The study starts with analysis the genebank information management by historical periods as introduction to the project initiative (Figure 1). The results provide insights into existing workflows and highlighted the roles of key responsible actors.

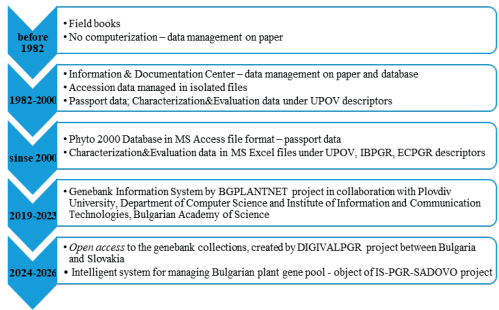


Figure 1. Historical periods of genebank documentation

The current digitalization activities in Bulgarian genebank follow the modern approaches aimed at compliance with the European policy for standardization of information in relation to sustainable conservation, *open access* to gene pool and equitable sharing of the benefits of these valuable resources among all participants in the agro-food chain. The GeneBank Information

System is designed for a comprehensive description of accessions by passport, evaluation and characterization data, as well as managing of all storage and monitoring processes. The automatic output in excel file format according to standard descriptors makes easy and effective transfer of data for Bulgarian accessions to EURISCO intranet system.

According to EURISCO there are 66,555 preserved seed samples at IPGR - Sadovo from 70,990 totally registered as Bulgarian gene pool (Table 1). 25.65% from the *ex situ* collection in the National Seed Genebank is with local origin. Through the National Focal Point, accessions from the breeding collections of other institutes of the Agricultural Academy have been included in the European search catalogue EURISCO.

Table 1. Status of the Bulgarian *ex situ* National Inventory in EURISCO

Institute FAO code	Holding institute name	Number of accessions	Acc. with Bulgarian origin
BGR001	Institute of Plant Genetic Resources, Sadovo	66,555	17,073
BGR005	Institute of Rose and Essential-oil Plants, Kazanlak	563	4
BGR007	Institute of Maize, Knezha	13	13
BGR015	Institute of Forage Crops, Pleven	2	2
BGR029	Dobrudzha Agricultural Institute, General Toshevo	3,857	1,829
Total number of accessions		70,990	18,921

The data for monitoring of crop wild relatives in Bulgaria covers 243 populations, available in EURISCO website for *in situ* preservation with prioritized taxa: *Achillea*, *Aegilops*, *Astragalus*, *Bromus*, *Calamagrostis*, *Clinopodium*, *Dactylis*, *Daucus*, *Glycirrhiza*, *Hedysarum*, *Heracleum*, *Lepidium*, *Limonium*, *Lotus*, *Mentha*, *Paeonia*, *Serratula*, *Silene*, *Stachys*, *Trifolium*. The neighbour country Romania is also characterized by a high number of crop wild relatives, the Şandru (2021) presents a checklist of 525 native species. The stated

examples confirm the presence of rich biodiversity in the Balkans.

Development and implementation of innovative technologies for the management of plant genetic resources in Bulgarian genebank include the following steps:

(1) Improve the open access to the plant gene pool by all users, regardless of their knowledge through ontologies;

(2) Managing the germination tests and alert warning system for needed control checks;

(3) Implementation of a control system using QR codes facilitate and optimize the genebank activities;

(4) Digitalization of results from evaluation of accessions with external devices – seed analyser, which will increase the quality of the decisions taken for the storage process;

(5) Monitoring the conditions in the medium- and long-term storage chambers, in the laboratories and in the seed drying room with sensor network.

The genebank has refrigeration systems set up to maintain specific seed storage conditions depending on whether the storage is medium- or long-term. The technical staff inspects these installations daily and monitors the status of the storage conditions. The proposed for construction sensor network provides constant monitoring of the conditions in the cold storage chambers, providing the genebank employees with continuous information about the state of the seeds. The software component allows the monitoring of sensor data in real time, which facilitates the detection of potential problems with the refrigeration installations and enable a quick response if a change in storage conditions or additional test is required. A sensor network specification to alert the genebank staff when there are problems with the refrigeration installations, in the dryer room and laboratories is created.

The smart technology in germplasm conservation reduces the level of risk for loss of accessions and allow wider access of users to the resources, stored in the genebank.

Digitalization and open access to the gene pool develop the social interest in plant genetic resources. The available data increases the possibilities for partnership of the Bulgarian genebank with agricultural and horticultural crops breeders who are searching for valuable

donors of important traits in the direction of sustainable agriculture in climate change conditions.

To effectively manage the implementation of the IS-PGR-SADOVO project and ensure the achievement of the goals, the main activities are grouped into six work packages (Figure 2).

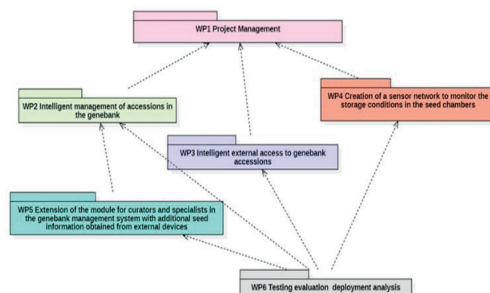


Figure 2. Strategically work packages and interaction between them

Curators conduct experiments with accessions, listed in their collections, and record and analyse their results. When a new accession is registered in the genebank documentation system with its passport data, it refers to a designated collection for storage, study, reproduction and multiplication for germplasm free exchange. The experiments are currently related to the measurement of evaluative characteristics by unified international descriptors.

The measuring system for analysis of accessions scans the seeds and evaluate the total number of seeds, 1,000 grain weight, grain size (length, width), determination of dark or light grains, fractions by size (length, width), calculation of hectolitre mass, determination of purity of the accession, etc. A relational database with biometric assessment of different accessions and plant species maintained in the genebank is created. The system provides capabilities to detect colour abnormalities in seed accessions and to record colour images for documentation purposes. The data obtained from the measurement system is incorporated into the Intelligent Management System of the Bulgarian plant gene pool, stored in the genebank of IPGR-Sadovo, and access to a wide range of users will be provided.

All data in the GeneBank Information System is provided by curators, conservation and

Passport data present basic information on crops – a unique identifier of accession (ACCNUMB), genus, species, accession name, as well as information about holding institute, country of origin, status of accessions, source of the material, date of collection, type of storage, whether the genotype has safety duplication in another genebank, etc. The accession number consists of year, genus code, species code and the serial number of the accession in the crop collection. Passport database also contains information about the crop wild relatives, received from monitoring and *in situ* preservation such as taxonomy, geographical data and description of the collection site. All passport data is compliant with the FAO/Bioversity descriptors (2017; 2022). Figure 3 presents the main screen of GeneBank Information System with passport data of the crops.

Figure 3. Passport data of the crops in GeneBank Information System

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Figure 4. Evaluation characteristics in GeneBank Information System

Figure 5. Storage documentation in GeneBank Information System

Вопрос	Тип	Критерий оценки	Колличество	Место оценки
1	Работа - среднесрочно	Зеленович	1 гр. 350 человек, 1 листа	УБ
BGR1225	Длительность	Жилин	27 гр. 1 листа	

Критерии проверки

Дата	Классический метод, %	Классический, %	Визуальный, %
2023-02-01	98,7	98,5	6,0

For each sample, the system allows to see the reproductions that are associated with it, in what storage they are and what control checks have been made for each of them. Work is currently underway to import historical data on the reproductions and the control checks carried out for them into the system database. Accessions are distributed free of charge based on signed SMTA (Standard Material Transfer Agreement).

CONCLUSIONS

The study prioritizes GeneBank Information System innovation efforts and strategically plan improvements over short-, medium-, and long-term horizons. This approach supports a strategic focus on using smart technologies for monitoring and management of genebank activities.

The digitalization of gene pool management processes is a prerequisite for increasing the quality of data, better control and sustainable preservation of plant genetic resources.

Access to information on the gene pool qualitatively increases the cooperation of the National Genebank with the Bulgarian breeding programs in connection to the creation of sustainable new varieties that meet the challenges of the present and future environment conditions.

Interdisciplinary collaboration between agriculture and software engineering scientists is a successful approach to continue providing professional support to maintain a continuous improvement process of genebank information management system.

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