Viability of agricultural crop seeds in unregulated natural storage facilities of the Arctic Circle

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Abstract. Genetic collections of plants are mainly contained in the form of seeds, the conservation of which is an important state task. To maintain the collection in a living state, it is necessary to periodically check the germination of seeds, and if necessary, carry out reseeding of seeds in order to reproduce them. The genetically determined shelf life of seeds can be significantly extended by creating optimal storage conditions. Therefore, it is necessary to search or create environmental conditions under which the seeds could remain viable for as long as possible. There are modern high-tech seed storages in the world, but in case of emergency, emergency situations, natural storages will be in a better position, one of which is located on the Taimyr Peninsula. In 1974, an experiment was begun to study the preservation of grain, seeds, and various products in different types of packaging under permafrost conditions with the participation of a number of research institutions. Grain cereals of various samples have been in long-term storage since 1980. Intermediate seeding and analysis of seeds showed a high degree of viability and prolongation of economic suitability. In 2016, the All-Russian Research Institute for Selection and Seeding of Vegetable Crops (now the Federal Research Center for Horticulture) joined in a long experiment. The employees of breeding laboratories selected a collection of seeds of seven main types of vegetable crops, the samples were laid in three replicates, in accordance with the planned three periods of harvesting, for a long shelf life in permafrost conditions.

1. Introduction
Seeds are a strategic commodity, and the national seed system is a reliable guarantee of the food security of any country. It is no coincidence that there is a tough battle in the world for seed markets. Huge multinational companies, having seized the market, are imposing their conditions on producers, i.e. agrochemicals, pesticides, agricultural machinery and much more are bound with the seeds.

Seeds are a convenient form of storage of genetic material, as the samples are small in volume, require relatively little maintenance and remain viable for a long period. Preservation of the genetic diversity of cultivated plants is an important state task. In addition to the governments of large and developed countries, a number of international organizations (FAO, UPOV, ISTA) also pay special attention to this issue. Genetic collections in the world number in the hundreds [1, 2].

The largest genetic collections are collected in the USA, China, India and Russia (Fig. 1)
In our country, a collection of the All-Russian Institute of Plant Genetic Resources named after N.I. Vavilova has more than 322 thousand plant samples [3]. An urgent need is to maintain the genetic collections of cultivated plants in a living state. Seeds are a convenient form of storage of genetic material, as the samples are small in volume, require relatively little maintenance and remain viable for a long period of time. In order for the content of genetic collections to be justified, high-quality seed samples must be stored. To maintain the collection in a living state, seed germination is periodically checked or seed reseeding is carried out in order to reproduce them. Reseeding a certain number of collection samples is quite laborious and expensive in terms of costs, time and money, often do not guarantee the genetic integrity of seeds, preservation of their genetic potential [4].

| Country       | Number samples | Number species | Number genera |
|---------------|----------------|----------------|---------------|
| USA           | 508994         | 11815          | 2128          |
| China         | 391919         | –              | –             |
| India         | 366333         | 1495           | 723           |
| Russia        | 322238         | 2025           | 256           |
| Japan         | 243463         | 1409           | 341           |
| South Korea   | 154695         | 1700           | –             |
| Germany       | 148128         | 3049           | 801           |
| Brazil        | 107246         | 670            | 212           |
| Canada        | 106280         | 1166           | 257           |
| Ethiopia      | 67554          | 324            | 151           |

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There are modern high-tech seed storages in the world. The largest such facility is the World Seed Store on Svalbard Island, with a capacity of 4.5 million seed lots. There, at a depth of 120 m, a low temperature (−18 °C) and limited oxygen supply are maintained. Such optimal conditions should provide low metabolic activity and slow down the aging of seeds [5]. In our country, a natural cryogenic storage of seeds has recently been built in Yakutia. So far, the seed collection has been estimated at more than a hundred thousand lots, but is rapidly growing [6]. It must be remembered that in case of emergency, emergency situations, natural storage facilities will be in a better position. One of these natural repositories is located on the Taimyr Peninsula in permafrost. The starting point for the beginning of the long-term experiment was a unique discovery in 1973 by the members of the Komsomolskaya Pravda expedition, who examined the western coast of the Taimyr Peninsula in order to study and search for historical monuments of the first Russian explorers of the North. A warehouse of food products found in permafrost at a depth of 1.3 m was discovered by the head of the Russian Polar Expedition, E.V. Tollem back in 1900. The results of the organoleptical and biochemical analysis of the products found showed their good preservation and high qualities. Thus, the discovered unique food warehouse, which had been lying in permafrost for more than 70 years, aroused great scientific and practical interest from the point of view of studying the conditions of long-term storage of products. Therefore, it was decided to continue the scientific experiment on the long-term storage of food in permafrost. In 1974, an experiment was begun to study the preservation of various products in different types of packaging under permafrost conditions, and a "Program for the study of the possibility of long-term storage of food products in the conditions of permafrost on the Taimyr Peninsula" was drawn up and approved, with the participation of a number of research institutions.

2. Methods and materials
The research material was grains of soft winter wheat (2 lots), soft spring wheat (2 lots), winter rye, barley, oats; seeds of eight types of vegetable crops in the amount of 27 variety samples.
Sowing qualities of grain and seeds were determined in laboratory conditions in accordance with GOST R 52325-2005 [7].

3. Results
In 2016, another expedition took place, as a result of which a new stash was made in two directions of industrial and food products (Fig. 1).

In parallel, 20 laboratory samples were removed from the storage, including wheat and rye grains, buckwheat and rice in various packages, soybeans, vegetable oil and other products. In laboratory conditions, on the basis of the FIC Nemchinovka, an analysis of the sowing qualities of grain after long-term storage in 2016 was carried out. It is noteworthy that after 37 years of storage, spring wheat grains showed high germination energy (72.5 %) and germination capacity (82.0 %), while under natural storage conditions their longevity does not exceed 4–5 years. Winter wheat, on the contrary, could not stand a long period of storage and deteriorated (the germination rate was 17.8 %). The sample lot of seeds of wheat, rye, barley and oats stashed in 2009, after seven years of storage, also retained high viability: the germination energy was 85–98.2 % and the germination rate was 88.5–99.0 %. According to GOST R 52325-2005, the requirements for sowing qualities of the seeds are as follows: 92 % of germination capacity for original and elite seeds and that of 87 % for reproductive seeds for marketable crops. Accordingly, the seeds of cereal crops of 2009, after seven years of storage, retained their sowing qualities at the level of original, elite and reproductive seeds.

![Figure 1. Expedition to the natural storage of seeds and products, Taimyr peninsula, 2016](image-url)
and retain their viability from 1 to 8 years, on average. Many types of seeds require the extension of their economic suitability due to optimal storage conditions [9, 10].

Table 2. Viability indicators of grain cereal crops after long-term storage, 2016 (%)

| Culture, form, variety | Crop year | Germination energy | Germination capacity | Ungerminated seeds | abnormal | Including swollen | rotten |
|------------------------|-----------|--------------------|---------------------|--------------------|----------|------------------|--------|
| Spring soft wheat      | 1979      | 72.5               | 82.0                | 18                 | 8.2      | 6.0              | 3.8    |
| Soft winter wheat      | 1979      | 3.0                | 17.8                | 82.2               | 22.2     | 24.5             | 35.5   |
| Soft winter wheat      | 2009      | 89.2               | 91.2                | 8.8                | 4.5      | 2.8              | 1.5    |
| Spring wheat, Esther   | 2009      | 85.0               | 88.5                | 11.5               | 5.5      | 3.5              | 2.5    |
| Winter rye, Valdai     | 2009      | 85.0               | 88.5                | 11.5               | 3.5      | 1.8              | 6.2    |
| Barley, Vladimir       | 2009      | 98.2               | 99.0                | 1                  | 0.8      | 0.2              | –      |
| Oats                   | 2009      | 86.2               | 90.8                | 9.2                | 4.0      | 3.5              | 1.8    |

Table 3. List of samples of seeds of vegetable crops for stashing for long-term storage, 2016

| No. | Culture, species | Varieties         | Crop year |
|-----|------------------|-------------------|-----------|
| 1   | White cabbage    | Amager 611        | 2015      |
| 2   | Cucumber         | Vodoley           | 2011      |
| 3   | Tomato           | Gnom              | 2006      |
| 4   | Pepper           | Khrizolit         | 2014      |
| 5   | Bulb onions      | Atas              | 2014      |
| 6   | Celery           | Egor              | 2015      |
| 7   | Parsley          | Sakharnaia        | 2015      |

According to scientists, the replacement of genetically diverse classic varieties with higher-yielding varieties and hybrids with a high degree of nuclear and cytoplasmic homogeneity in many countries of the world has become the main cause of devastating epiphytoties in many crops [11]. In addition, despite the rapid varietal change in modern agriculture, a return to the old genetic sources in search of the necessary traits and properties is considered a necessity. Some varieties, the seeds of which are stored, represent the Golden Fund of the Russian selection, the preservation of which is very important for future generations [12]. Varieties of white cabbage (Amager, Zimovka) carrots (Nantes, Moscow winter), parsley (Sakharnaia) have been in the State Register of the Russian Federation of selection achievements for more than 50–70 years.

4. Conclusion
Thus, on the Taimyr Peninsula, storage of grain cereal crops with laying at different times, starting in 1974, as well as a collection of vegetable seeds planted in 2016, continues. Further expeditions are planned with the aim of laying new samples and removing samples from storage for quality analysis in 2025, 2035 and 2050. It should be noted that vegetable seeds are included in this experiment for the first time and the expected results should be of undoubted scientific interest. The nearest collection of samples is scheduled for 2025. Consequently, the experiment will end with the participation of more than one generation of researchers.

Acknowledgment
The authors are grateful to the leadership of the Federal Agency "Rosrezerv", the Russian Geographical Society for organizing and participating in the polar expedition.

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