

ABSTRACT

of the dissertation for the degree Doctor of Philosophy (PhD)
in the educational program «8D05108 – Geobotany»

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“Assessment of ecological and biological characteristics of perennial wheat in Kazakhstan and its impact on the conservation of biodiversity and soil fertility”

General characteristics of the research. The dissertation research is aimed at a comprehensive evaluation of the ecological, biological, and biochemical characteristics of perennial wheat in various agroecological zones of Kazakhstan, as well as its role in biodiversity conservation and in improving soil fertility in natural and agroecosystems.

Relevance of the research. One of the most urgent global problems today is global warming. Excessive accumulation of carbon dioxide in the atmosphere leads to large-scale and persistent warming of the planet, causing changes in ecosystems and degradation of natural resources. In this context, the introduction of perennial crops into agricultural practice as an effective means of long-term soil carbon sequestration has become increasingly important. Under the conditions of Kazakhstan, biodiversity conservation, enhancement of soil fertility, and ensuring ecological sustainability of agricultural landscapes are among the most pressing environmental challenges. In recent years, the use of perennial crops in agriculture has been recognized as an important approach to reducing soil erosion, increasing agrobiodiversity, and decreasing yield variability. Geobotany studies the patterns of plant distribution in natural and agroecosystems, their dependence on ecological factors, and the dynamics of plant communities. Therefore, studying the biological and ecological characteristics of perennial wheat across different natural and climatic zones of Kazakhstan is highly relevant. Such research makes it possible to determine the contribution of perennial wheat to interactions with local plant communities, soil structure improvement, accumulation of organic matter, development of soil microflora, and biodiversity conservation. Perennial wheat is considered one of the most environmentally sustainable crops. Its deep and powerful root system stabilizes soil, reduces erosion processes, improves soil structure, and promotes the accumulation of organic carbon in soils. From an ecological perspective, the introduction of perennial wheat increases the stability of vegetation cover in agricultural landscapes, enriches species composition of plant communities, and supports the balance of soil biocenoses. From an economic point of view, perennial wheat produces yields for several consecutive years, reducing sowing costs and increasing production efficiency. In the dry steppe and semi-desert regions of Kazakhstan, this crop can efficiently use soil moisture and serve as a viable solution for the utilization of low-productivity lands. The study of the geobotanical characteristics of perennial wheat is therefore of high scientific and practical relevance for biodiversity conservation, soil fertility enhancement, and the formation of climate-adaptive sustainable agricultural systems.

Research period: 2021–2024

Research aim. To conduct a comprehensive study of the ecological, biological, and biochemical characteristics of perennial wheat in different agroecological zones of Kazakhstan, and to assess its role in biodiversity conservation and in improving the physical, chemical, and biological fertility of soils in natural and agroecosystems.

Research objectives

1. To determine the adaptability of the morphological structure of perennial wheat to climatic and soil conditions, including phenological phases, root system architecture, leaf anatomical characteristics, and mechanisms of perennial viability;
2. To provide a geobotanical characterization of perennial wheat agrocenoses, determine the floristic composition of plant communities, and assess biodiversity indicators using Shannon, Simpson, and Pielou indices;
3. To assess the dynamics of organic carbon accumulation in soils under perennial wheat, its CO₂ sequestration capacity, soil chemical properties (pH, humus content, macroelements), biological activity, soil microbiome composition, and overall soil fertility;
4. To determine the levels of proteins, carbohydrates, amino acids, fatty acids, mineral elements and other phytochemical components in grain and biomass of perennial wheat, to compare them with annual wheat, and to analyze variation under ecological factors;
5. To substantiate the ecological and economic feasibility of cultivating perennial wheat in different regions of Kazakhstan.

Research Objects. The objects of the study were perennial wheat varieties, including the Russian variety *Sova*, a total of ten accessions: five wheat–wheatgrass hybrids (No. 39-02-1, 39-04-1, 39-04-4, 34-06-1, 39-04-6) and five American wheatgrass–wheat hybrids (No. 701, 703, 702, 704, 801). Annual wheat varieties *Saratovskaya 29*, *Kargaly-9*, *Stepnaya 50*, and *Tulkibas* were used for comparative analysis. For the first time under the conditions of Kazakhstan, the most promising breeding varieties and accessions of perennial wheat obtained through interspecific hybridization between *Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey and *Triticum aestivum* L. were tested.

Research methods:

1. Geobotanical methods. Field geobotanical surveys were conducted to determine species composition, projective cover, and phytocenosis structure. Transect and sample plot methods were used to assess distribution, dominance, biomass, and vegetation density. Phytoindication analysis was applied to assess soil and climatic conditions based on plant indicators.

2. Morphological and biological methods. Phenological observations recorded growth stages (emergence, tillering, stem elongation, heading, flowering, ripening). Root system characteristics were studied using the monolith method. Aboveground and belowground biomass were measured. Stress tolerance to drought, salinity, and temperature fluctuations was evaluated.

3. Biochemical analysis. Protein content (Kjeldahl method), carbohydrates (photometric method), fatty acids (gas chromatography), amino acids (HPLC), mineral elements.

4. Soil analysis. Physical, chemical, and biological soil properties were assessed, including humus content (Tyurin method), pH, macrolelements, microbial activity, and organic carbon content (Walkley–Black or CN analyzer).

5. Ecological efficiency assessment. CO₂ sequestration was calculated based on changes in soil organic carbon. Erosion resistance and vegetation stability were evaluated using biodiversity indices.

6. Economic analysis. Production costs, profitability, yield comparison, labor inputs, water and fertilizer efficiency were analyzed.

7. Statistical analysis. ANOVA, correlation and regression analyses, biodiversity index calculations were performed using Statistica, R, and SPSS software.

Scientific Novelty. For the first time in the southern and southeastern regions of Kazakhstan, a comprehensive study has been conducted on the adaptive characteristics of perennial wheat. The morphological and anatomical features, phenology, root system development, and long-term viability mechanisms have been established in relation to the regional climatic and soil conditions. High accumulation of organic carbon in the soils of agro-ecosystems featuring perennial wheat, as well as its superior carbon sequestration capacity, has been demonstrated. The positive impact of perennial wheat on soil biota and the increase in microbial populations have been identified for the first time. An increase in the biodiversity of plant communities was established according to the Shannon, Simpson, and Pielou indices, indicating the ability of perennial wheat to enhance the stability of biocenoses in degraded agrolandscapes. For the first time, a comparative analysis of the biochemical composition of perennial and annual wheat grains was performed, revealing differences in amino acid and fatty acid profiles. The high biological and nutritional potential of perennial wheat has been proven. Furthermore, the changes in the chemical composition of perennial wheat straw during treatment with enzymes from the microorganisms *Trichoderma harzianum* and *Aspergillus awamori* were studied for the first time, confirming its biotechnological potential.

Practical significance. The research findings establish a scientific and practical foundation for introducing perennial wheat into the agricultural production of Kazakhstan's southern and southeastern regions as an environmentally and economically efficient crop. Utilizing perennial wheat as an alternative to, or in conjunction with, traditional annual wheat helps curb soil degradation, reduce wind and water erosion, and enhance the ecological stability of agrolandscapes. The patterns of soil organic carbon accumulation identified during the study allow perennial wheat to be considered an effective biological tool for carbon sequestration under climate change conditions. The obtained data can be utilized in developing national and regional agroecological programs aimed at reducing greenhouse gas emissions and optimizing the carbon balance.

The study has demonstrated the high suitability of perennial wheat straw for enzymatic and microbiological processing, confirming its potential practical use as

a raw material for the production of sugars, amino acids, protein supplements, biofuels, and other biologically valuable products.

Main provisions submitted for defense:

– It has been proven that the morphological structure of perennial wheat is highly adapted to the climatic and soil conditions of Kazakhstan, as evidenced by the flexibility of phenological phases, a deep and branched root system, the predominance of xeromorphic leaf anatomy traits, and the formation of long-term viability mechanisms.

– It was established that in agro-ecosystems with perennial wheat, the geobotanical structure of plant communities forms as a stable phytocenosis, and the values of the Shannon, Simpson, and Pielou indices indicate a high level of biodiversity.

– It was revealed that the long-term cultivation of perennial wheat promotes the accumulation of soil organic carbon and enhances CO_2 sequestration processes; this is accompanied by improvements in soil chemical parameters (pH, humus content, macro- and microelements) and an increase in microbial populations, ensuring a sustainable rise in soil fertility.

– It was established that the biochemical composition of the grain and vegetative mass of perennial wheat (proteins, carbohydrates, amino acids, fatty acids, and mineral elements) differs from that of annual wheat and varies in accordance with specific environmental factors.

– It has been proven that the cultivation of perennial wheat across various natural and zones of Kazakhstan is ecologically and economically viable, contributing to the prevention of soil degradation, the conservation of biodiversity, the reduction of agrochemical loads, and the formation of sustainable agricultural systems.

Author's contribution. The author made a significant contribution to defining the research concept, experimental design, data collection, analysis, interpretation, and generalization of results.

Research project framework. The dissertation was carried out within the framework of the project AP09259457 “**Introduction of Perennial Wheat into Agricultural Practice to Preserve Biodiversity and Soil Fertility in Southern and Southeastern Kazakhstan**” (2021–2024).

Approbation of the research. The results of the dissertation research obtained within the framework of the project are confirmed by patents, and the main findings have been presented and discussed at international scientific conferences:

- utility model patent “Method for creating herbal agroecocenoses under changing climate conditions” (Almaty, Kazakhstan, 2022);

- utility model patent “Method for stimulating the growth and development of agricultural crops” (Almaty, Kazakhstan, 2025);

- a report at the International Forum “Modern Trends in Sustainable Development of Biological Sciences” with publication in Proceedings BIO Web of Conferences 100, 04048 (Almaty, Kazakhstan, 2024);

- publication in the journal Natural Product Research (2024), Scopus Q1, 78th percentile;

- publication in the journal International Journal of Design and Nature and Ecodynamics, Scopus Q2, 50th percentile;
- publication in the journal Experimental Biology, No. 4 (89), 2021, pp. 73–87.

Publications. The research findings have been published in 6 scientific works, including 3 articles in international journals indexed in the Web of Science and Scopus databases, 1 article in a republican scientific journal included in the list recommended by the Committee for Quality Assurance in the Field of Education and Science of the Republic of Kazakhstan, 2 utility model patents, and 1 publication in the proceedings of the international scientific conference BIO Web of Conferences (Scopus).

Structure of the dissertation. The dissertation consists of an introduction, review of national and international literature, materials and methods, results and discussion, conclusions, and a reference list of 174 sources. The total volume is 121 pages, including 22 tables, 39 figures, and 1 appendice.