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STUDY OF VARIETAL TECHNOLOGY OF SOYBEAN GROWING IN THE CONDITIONS OF CLIMATE CHANGE

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The study is devoted to the study of the territorial transformation of the «soybean belt» in Ukraine and the world under conditions of climate change on the basis of soil conservation. The prerequisites for the establishment of a new stage in the production of soybean seeds are detailed, which will contribute to the rational use of hydrothermal resources of the region, the increase of production volumes, the biologicalization of agriculture, and the production of high-quality, organic products. It was found that the organic production of soybean seeds is one of the strategic directions of the accelerated development of the agro-industrial complex of Ukraine and the main goal of the European Green Course, which regulates the transformation of Europe into a climate-neutral continent . The study was conducted, which is devoted to the issue of Ukraine's achievement of the goals of sustainable development: Goal 2. Overcoming hunger, achieving food security, improving nutrition and promoting the sustainable development of agriculture, which are aimed at solving the urgent tasks of technological renewal and development of the agro-industrial complex on the basis of the development of bio-organic models of varietal technology cultivation of leguminous crops with orientation to the level of adequate productivity of arable land and climatic changes. Along with this, it is highlighted that in the countries of sustainable agriculture, in particular the EU, considerable attention is paid to greening and reducing the negative impact of intensive soybean cultivation technologies on the environment.
The relevance of the article is strengthened by the tasks of the 1st stage of applied research on the topic «Development of scientific and technological support for increasing soil fertility and rational use

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of the potential of biological resources» (0124U000444), which is carried out at the expense of the state budget fund (2024–2026).

Key words: *soybean, variety, climate change, soil conservation, biological preparations, productivity.*

ДОСЛІДЖЕННЯ СОРТОВОЇ ТЕХНОЛОГІЇ ВИРОЩУВАННЯ СОЇ В УМОВАХ ЗМІН КЛІМАТУ

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Дослідження присвячено вивченню територіальної трансформації «соєвого поясу» в Україні та світі в умовах змін клімату на засадах ґрунтозбереження. Деталізовано передумови для становлення нового етапу у виробництві насіння сої, що сприятимуть раціональному використанню гідротермічних ресурсів регіону, збільшенню обсягів виробництва, біологізації землеробства, одержанню високоякісної, органічної продукції. З'ясовано, що органічне виробництво насіння сої є одним із стратегічних напрямків прискореного розвитку агропромислового комплексу України та головною ціллю Європейського Зеленого Курсу, що регламентує перетворення Європи на кліматично нейтральний континент. Проведено дослідження, яке присвячене питанням досягнення Україною цілей Сталого розвитку: Ціль 2. Подолання голоду, досягнення продовольчої безпеки, поліпшення харчування і сприяння сталому розвитку сільського господарства, які спрямовані на вирішення актуальних завдань технологічного оновлення та розвитку агропромислового комплексу на основі розробки біоорганічних моделей сортової технології вирощування зернобобових культур із орієнтуванням на рівні адекватної продуктивності ріллі та кліматичних змін. Поряд із цим зазначено, що в країнах сталого сільського господарства, зокрема ЄС, значна увага приділяється екологізації та зменшенню негативного впливу інтенсивних технологій вирощування сої на довкілля завдяки використанню біологічних препаратів. Актуальність статті підсилюється завданнями першого етапу прикладного дослідження на тему «Розробка науково-технологічного забезпечення підвищення родючості ґрунтів та раціонального використання потенціалу біоресурсів» (0124U000444), що виконується за рахунок видатків фонду державного бюджету (2024–2026 рр.).

Ключові слова: *соя, сорт, зміна клімату, ґрунтозбереження, біологічні препарати, урожайність.*

Introduction

Due to climatic changes, today's natural and climatic conditions make it possible to grow soybeans almost throughout the territory of Ukraine. Improvements in the technological methods of cultivation with a scientifically based selection of the assortment led to an increase in the yield level during 2013–2023 by an average of 1.9 t/ha. Therefore, the selection of adapted varieties is the best agrotechnological technique for agricultural practice with a simultaneous reduction of the impact on the environment due to limiting factors, and ultimately on the yield level of leguminous crops. The selection of the variety is able to provide plastic adaptation properties to the edapho-climatic conditions of cultivation in order to obtain high and stable yields under modern climatic changes. This question has become especially acute in connection with the trends of climate neutrality, among scientists and practitioners there is a task related to the development of technological aspects of cultivation, which will ultimately ensure an increase in the level of the harvest by ensuring the appropriate quality indicators. Extremely important elements in increasing the yield level while simultaneously improving the qualitative indicators of soybean seed production are the use of scientifically based plant nutrition systems, the introduction of the latest effective growth regulators. the relevance of the scientific article is strengthened.

Soybeans are classified as one of the most important food, fodder, and technical crops of world crop production, capable of providing complete vegetable protein to the needs of the country's population and the livestock industry (Mazur et al., 2018). The high universality of the use of the culture, the production of which has great agrotechnical, food and fodder importance, sets before the cooperating global agrarians, including Ukraine, the task of finding ways to increase the volume and efficiency of its production, improve the quality and preserve the fertility of the soil (Kots et al., 2021). At the same time, in modern economic conditions, despite the fact that more attention has been paid to the development of domestic soybean seed production and positive changes have been outlined not only in the production, but also in the consumption of soybeans, there is a shortage of soybean seeds on the Ukrainian

market, as a result of the war on the territory countries (Didur et al., 2020).

Therefore, in conditions of insufficient economic support from the state, ensuring the parity of soybean prices compared to other crops reduces its competitiveness and attractiveness for farmers. In addition, the possibilities of expanding soybean crops, introducing scientifically based varietal zoning adapted to the conditions of specific regions, including in the south of the country, are not fully realized (Mazur et al., 2021 a).

The rapid growth of soybean production in the world and in Ukraine is due to the fact that the culture is a source of vegetable protein, much cheaper than animal protein, greater demand in the countries of its historical consumption, high profitability and demand by various industries. Soybean cultivation in the conditions of the forest-steppe of Ukraine is becoming more and more relevant and requires development with the simultaneous improvement of varietal technological aspects of cultivation, with the use of adaptation-plastic varieties to environmental conditions, research on the optimal terms of sowing seeds, the density and field germination of crops, bacteriization of seeds, sowing rates and power elements. Therefore, in order to obtain a high yield, it is necessary to set aside the best fertile fields and predecessors for soybeans, sow high-yielding varieties, and master adaptive varietal growing technology. In the future, soybeans, as a strategic crop for Ukrainian agriculture, can be sown on a fairly large area of the soybean belt, which includes the Forest-Steppe, northern, central, and southwestern Steppes, the Forest-Steppe regions of Polissia, and the irrigated lands of the southern steppe, where its area can be increased to 4 million ha, production – up to 10 million tons and receipt of more than 450–600 thousand tons of biological nitrogen. This will provide the economy with about 150 billion hryvnias.

According to analytical and statistical data, it was found out (Mazur et al., 2021 b), that soybean occupies the majority of the total volume of production of oil crops (more than 60%). Also, the need and importance of soybean production is caused by the large-scale development of poultry farming in the territory of the Vinnytsia region. Therefore, against the background of a significant increase in the price of mineral fertilizers recently, with rational use, organic fertilizers, bacterial preparations and microfertilizers can become an effective alternative.

Material and methods

The relevance of the article is strengthened by the tasks of the 1st stage of the applied research on the topic "Development of scientific and technological support for increasing soil fertility and rational use of the potential of biological resources" (0124U000444), which will be carried out at the expense of the state budget fund (2024–2026).

The purpose of the work is to study the technological methods of growing soybeans as a factor in increasing soil fertility under climatic changes.

Results

Despite the fact that almost 78% of the Earth's atmosphere consists of nitrogen, it is unavailable to most plants (Tsyhanskyi, 2020). According to the analysis of literary sources (Pantsyreva et al., 2024) it was established that the air above one hectare of the field surface contains 80 thousand tons of nitrogen. However, it becomes available to plants only through symbiotic nitrogen fixation, which is carried out by nodule bacteria that are in a close symbiotic relationship with leguminous plants, in particular soybeans (Vyshnivskyi et al., 2020). Therefore, after sowing the inoculated seeds, nodule bacteria (*Rhizobia*) germinate in the form of thin hairs and infect the young roots of the plant. After penetrating the root hair, the bacteria cause intensive division of the root cells, as a result of which a nodule appears. The bacteria themselves develop in these nodules on the roots, taking part in nitrogen assimilation.

In the process of growth and development, soybean plants are exposed to various stress factors that can affect their seed productivity. Factors can exert stressful effects on plants and be implemented in a wide variety of manifestations: in the absence and excess of abiotic components humidity, air temperature, solar radioactive radiation, acidity of the environment, herbicide background, wind erosion, atmospheric pressure, degree of damage. Today, the most important direction in agricultural science and production is the study of the state of crops, which must be protected from the listed factorial influences in order to supplement the selection work on the breeding of adaptive plant varieties, where the key importance is assigned to biological preparations that form the adaptive properties of the plant, Chinchyk O., Patyka V., Mazur V., Tkachuk O., Didur I., Pantsyreva H., Bakhmat O.

Among Ukrainian scientists, issues related to technological renewal through the use of high-yielding varieties have been successfully implemented in cultivation technologies. Therefore, under a climate-neutral reference point, among scientists, the task of approbation of modern technological methods of cultivation, which can lead to the collection of maximum indicators of the level of productivity with simultaneous improvement of the quality of seed products in the specific natural and climatic conditions of Ukraine, is singled out. At the same time, an important component of increasing the yield and improving the quality of soybean seed production is the use of optimal component systems of mineral and biological nutrition, with the introduction of the latest bacterial preparations based on highly effective strains of nodule bacteria in simultaneous interaction with plant growth regulation. The latest experimental research on this issue is covered in the works of I. Didur, H. Pantsyreva et al. It has been established that the use of mineral fertilizers, growth regulators and seed sterilization improves the growth processes of plant groups with simultaneous stimulation of photosynthetic processes in order to improve resistance to uncontrollable factors, weather and climate conditions, harmful objects while increasing the level of seed production.

In agriculture, work is being carried out on a large scale regarding the use of various methods of accelerating the process of plant development, increasing yield and product quality. Biologization of production is of great importance in modern technologies.

The use of biological drugs is considered a sign of a highly developed economy of the state. The volume of production of fertilizing, protective and re-regulating biological preparations depends on this. Therefore, the production per unit area of biological preparations (Fig. 1) in Australia is about 6 million hectares, in the following countries: Canada up to 4,000,000, India – 3,000,000, Great Britain – almost 500,000, Yugoslavia – up to 500,000, Romania – about 500,000, the Republic of Poland – 500,000 each, Hungary – up to 200,000. In the conditions of Ukraine, the production of biological preparations per unit area is about 200,000 hectares (Zabolotnyi et al., 2020).

Bacterial preparations based on strains of nodule bacteria that are capable of fixing molecular nitrogen from atmospheric air, providing the biosphere with bound forms of nitrogen. Therefore, the only possible way of additional accumulation of nitrogen is its transformation into humus, which is a specific substance of the soil (Parizad et al., 2020). The nodule bacteria of grain leguminous plants were the first to be used for the production of biofertilizers, as they are visually detectable and provide increased indicators of the level of nitrogen accumulation (Bakhmat et. al., 2023).

So, capable of accumulating from 70 to 280 kg/ha – in soybean crops, from 200 to 350 kg/ha in alfalfa crops in the second

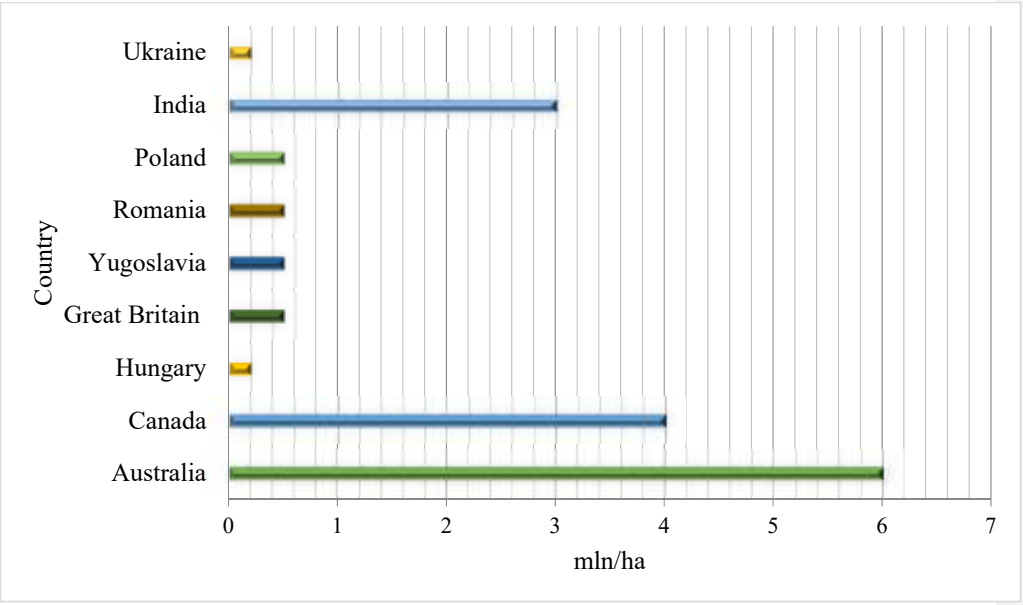

Fig. 1. World production of biological preparations per unit area, million ha

year of cultivation, and somewhat lower values were recorded in pea crops (from 40 to 70 kg/ha) (table 1).

In America, about 30% of the production need of agricultural practice in nitrogen is covered by mineral nutrition of plants, by 25% – by organic nutrition, and by 45% – by biological nitrogen nutrition. Therefore, in the USA, almost 1,000,000 hectares of leguminous crops are planted every year – biological preparations for soybeans (Optimize, Graphex), in North America – Tsnitragin and Paradr, in the republics of Uruguay and Argentina – Nitrosol and Nitrum, in Oceania (New Zealand and Australia) – Rhizocoat, Tropical Inoculant, Nodulaite, Nitrogerm, India – Ariss Agro, Egypt – Okadin, Poland, Germany, Hungary – Rhizonite-Thorore (Petrychenko, 2012; Honcharuk et. al., 2022). In Ukraine, more than 150,000 hectares of arable land are used for the production of biological preparations for soybeans with the following biological preparations: Risoline, Rhyzohumin, Biomag soy.

It has been established that soybean plants are a valuable source of balanced amino acid composition, as well as protein and fat content. However, the most important biological feature from an agronomic point of view is the biological fixation of nitrogen from the atmosphere. In the world, the share of biologically fixed nitrogen resources among leguminous crops in accordance with soybeans is almost 17.0 million tons or more than 70%, while in the USA plants biologically fix 5.4 million tons of nitrogen per unit area (Table 2).

Today, environmentally safe fertilizers characterized by a complex effect are bacterial preparations, thanks to the microorganisms on the basis of which they are created. Therefore, they are capable of fixing atmospheric nitrogen through the prism of transformation of phosphates in the soil. The ability to produce amino acids, which are growth activators and substances of abiotic origin (unnatural), is also recorded, which ultimately leads to the development of harmful objects. Biological preparations, nitrogen fixers, made on the basis of nitrogen-fixing bacteria, have a multifunctional effect on the growth, development of soybean plants and the formation of seed productivity (Myalkovsky et. al., 2023).

According to the processed data, it was established that the structure of the world production of oil crops, under soybeans is assigned to 60% of the cultivated areas. Therefore, over the course of fifty years, soybean crops grew from 24 million ha to 103 million ha with a yield level of 1.70–2.60 t/ha. It is known that soybean leaves 80–120 kg of nitrogen per hectare, equivalent to the application of up to 15 tons of organic fertilizers. In Ukraine, the cultivated area occupied by soybeans is 2.2 million ha, while the soil will receive the amount of nitrogen equivalent to 546 thousand tons of ammonium nitrate worth more than UAH 1 billion (Fig. 2).

In today's conditions, the world society is concentrated in three regions: in South America – these are countries such as Brazil, Argentina, Paraguay; in North America – the USA and Canada; Asia is China and India.

Table 1

The level of nitrogen accumulation in the soil due to nodule bacteria, kg/ha

Culture	**Accumulation, kg/ha**	**Remaining nitrogen in the soil, kg/ha**	**The equivalent dose of mineral fertilizers, kg/ha**
Soybeans	70–280	30–60	70–100
Peas	40–70	10–20	25–30
Alfalfa	200–350	10–20	25–35
Chickpeas	70–150	20–30	35–70
White lupine	80–270	30–50	60–90

Table 2

The share of arable land and the yield of soybeans by countries of the world

Country	**Share of soybeans to arable land, %**	**Yield level, t/ha**
Ukraine	3,51	1,78
USA	19,22	2,88
Canada	1,73	2,89
Australia	16,74	2,58
India	15,65	2,46

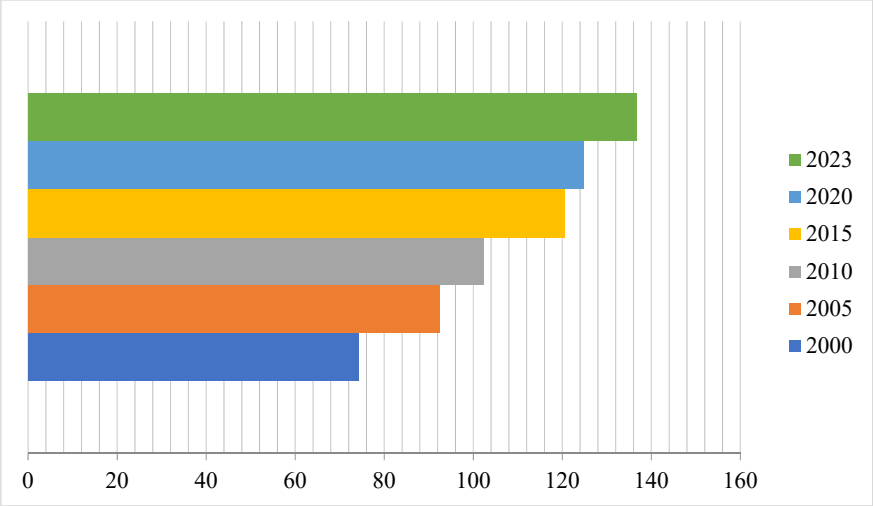

Fig. 2. World soybean seed production per unit area by year, million hectares (average for 2000–2023)

The leading countries in the production of soybean seed products can be clearly divided into 2 groups. The grouping is based on positions due to high yield and large areas of crops. Therefore, the highest levels of productivity in Brazil is 3.38 t/ha, in the USA, this average indicator of the level of productivity is 3.29 t/ha, in Argentina – 3.17 t/ha, in Paraguay – 3.10 t/ha, in Canada – 2.93 t/ha. With large planted areas and low yield of soybeans in Bolivia, the average yield level is 2.39 t/ha, and in China the average yield level reaches 1.79 t/ha, in India – 1.03 t/ha. In Ukraine, the average level of yield is 1.96 t/ha (Zhou et al., 2018).

The total rate of sowing in the world as of 2023 is 352.6 million tons. Traditionally, the global world leaders in the production of soybean seeds are the USA, Brazil, and Argentina, which last year collected almost 300 million tons of seed products, which in terms of world production is 82%. In the world balance, Ukraine ranks 8th, collecting more than 4 million tons of soybean seeds with a production share of 1%. Today, the leading producers include China, which collects almost 13.0 million tons of soybean seeds, India – 11.5 million tons, Paraguay – 10.3 million tons (Zhou et al., 2020).

Soybean cultivation in the conditions of the Forest-Steppe of Ukraine is gaining more and more relevance and the need for science-intensive solutions for technological renewal through the improvement of varietal technological methods of cultivation with the use of adaptation-plastic varieties resistant to abiotic factors, the establishment of the optimal and necessary periods of co-sowing, field germination and density of standing crops, seed sterilization, sowing rates and nutrients. Therefore, in order to obtain a high yield, it is necessary to set aside the best fertile fields and predecessors for soybeans, sow high-yielding varieties, and master adaptive varietal growing technology. In the future, soybeans, as a strategic crop for Ukrainian agriculture, can be sown on a fairly large area of the soybean belt, which includes the Forest-Steppe, northern, central, and southwestern steppes, the forest-steppe regions of Polissia, and the irrigated lands of the southern steppe, where its area can be increased to 4 million ha, production – up to 10 million tons and receipt of more than 450–600 thousand tons of biological nitrogen. This will provide the economy with about 150 billion hryvnias.

Therefore, due to climate changes and the creation over the last five years of the latest highly productive adaptive varieties at the Institute of Fodder of the National Academy of Agrarian Sciences of Ukraine with other research institutes, it led to an increase in the soybean belt to the north of the Forest Steppe and to the south of the Polissia of Ukraine (Mazur et al., 2018).

Territorial transformation of the «soy belt» implements the newest period in the production of soybean seed products, which contributes to the rationalization of the hydrothermal resource of the regions of Ukraine in the conditions of climate change, the increase of the gross production of soybean seeds per unit area, the biologicization of agriculture, and the production of high-quality, environmentally safe seed products (Fig. 3).

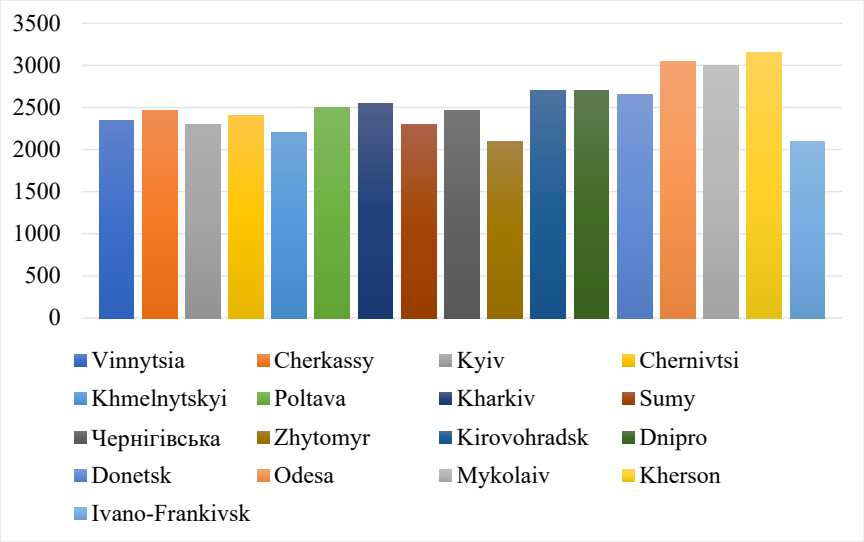

Fig. 3. The dynamics of the sum of the effective temperatures of the regions of Ukraine, °C

Soy, as the best predecessor in crop rotation for grain crops, in particular for corn, and short rotations for crop rotation soybean-corn will open real prospects for obtaining 80 million tons of seeds in Ukraine. Depending on the region, soybeans can occupy from 20 to 30% of arable land or more. Without soybeans, as a highly intensive leguminous crop and the best precursor, it is not promising to achieve the declared volumes of seed production. Together with soy, it is a strategic direction for the development of the agricultural sector, strengthening the economy and solving the food problem and increasing soil fertility.

Conclusions

In the conditions of climate change, the territorial transformation of the «soybean belt» is a prerequisite for the establishment of a new stage in the production of soybean seeds, which will contribute to the rational use of hydrothermal resources of the region, the increase of production volumes, the biologicalization of agriculture, and the production of high-quality, organic products. Organic production of soybean seeds is one of the strategic directions of the accelerated development of the agro-industrial complex of Ukraine and the main goal of the European Green Course, which regulates the transformation of Europe into a climate-neutral continent. Along with this, considerable attention in the countries of sustainable agriculture, in particular the EU, is paid to greening and reducing the negative impact of intensive soybean cultivation technologies on the environment. This is achieved, first of all, by reducing the use of pesticides and mineral fertilizers, finding ways to expand biological measures, inoculation, reducing the intensity of soil cultivation in accordance with the transition to eco-conserving technologies based on the selection of varieties that differ by maturity group in accordance with the amount effective temperatures.

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