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Study of Sowing Quality of Soybean Seeds Depending on Pre-Sowing Treatment of Seed

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ABSTRACT

Comprehensive assessment of sowing qualities of soybean seeds after pre-sowing treatment of seeds with biological preparations is a scientifically valuable and urgent problem of today, which made it possible to choose the optimal methods of realizing the genetic potential of productivity of modern soybean varieties. In laboratory and vegetation conditions, the sowing properties of soybean seeds were evaluated under pre-sowing seed sterilization. The aim of the research was to establish the sowing qualities of soybean seeds (varieties Slavna, Churaivna, Azymut, Tytan, Triada, Pallada, Samorodok), namely seed moisture, germination energy, field germination and linear hypocotyl parameters depending on the varietal composition and pre-sowing seed treatment with a bacterial preparation. Field and laboratory studies were conducted according to the following indicators: seed moisture, germination energy, field germination and linear hypocotyl parameters according to generally accepted methods. Research on the basis of the scientific research field of the Institute of Fodder and Agriculture of the Podillia National Academy of Sciences by the method of split plots in four repetitions according to the methodology of research in agronomy, p. Bohonyky, Vinnytsia region, Ukraine. It was established that the moisture content of the seeds of soybean varieties during 2020–2023 storage in uncontrolled climate conditions was within the normal range and did not exceed 13.4%. It was noted that the use of pre-sowing treatment of seeds with a bacterial preparation based on strains of nodule bacteria had a smaller effect on laboratory germination, and to a greater extent on the germination energy of soybean seeds. The maximum indicator was obtained on the Slavna soybean variety – 93.4% for the use of nitrogen-fixing bacteria (Rhizoline+Rhizosave) in the pre-sowing treatment of seeds. Laboratory germination had a significant tendency to increase up to 96.3–98.1% in variants with Svavna and Tytan varieties for the use of nitrogen-fixing bacteria (Rizolain+Rhizosave) in the pre-sowing seed treatment. Based on the obtained results, in order to stimulate the germination of soybean seeds, it is proposed to bacteriize them with complex inoculants, which is a more effective measure than inoculation with a monoculture of rhizobia. In the conditions of the Right Bank Forest-Steppe, in the variants where a bacterial preparation (Rizolain+Rhizosev) was used for pre-sowing seed treatment, the mentioned technological methods of growing can be used to improve the technology of growing soybeans.

Keywords: soybean, climate change, seed moisture, germination energy, laboratory germination, hypocoty.

INTRODUCTION

The steady trend towards warming and aridization of the climate led to the expansion and partial shift of the zone of industrial soybean cultivation from the Steppe zone to the Forest-Steppe zone of Ukraine. The zone of the right-bank forest-steppe of Ukraine has significant differences in the complex of soil and climatic conditions compared to the conditions of traditional cultivation. First of all, this is a change in the limiting factors of the environment, differences in the total income, seasonal and daily temperature dynamics, indicators of soil acidity.

In the complex, this necessitates the inclusion in the technology of additional control levers for the processes of crop formation, primarily due to changes in agrotechnologies of soybean cultivation (Monarkh et. al., 2019; Mazur et. al., 2020; Petrychenko et. al., 2000; Jansson et. al., 2019; Dumpis et. al., 2021; Zhao et. al., 2022).

A promising resource of an alternative source of increasing the productivity of crop production is the use of microbial preparations, among which a significant share is bacterial preparations based on nitrogen-fixing microorganisms. Legume-rhizobial symbioses formed by nodule bacteria and leguminous plants are characterized by a high nitrogen-fixing potential, the result of which is the accumulation of nitrogen in the soil up to 200–500 kg/ha per year (Dumpis, et. al., 2021; Zhao et. al., 2022). The development of organic production of plant seed products is relevant today due to a number of ecological, economic and social advantages. The intensification of agricultural production, which is taking place all over the world, is accompanied by a negative impact on the environment and the deterioration of the natural fertility of the soil, without which agriculture is impossible. Organic seeds are more useful for consumers due to the minimization of negative health effects of toxic and persistent chemicals (Piwowar et al., 2021; Petrychenko et. al., 2014; Mazur et. al., 2021; Marconi et. al., 2015; Mahmood et. al., 2019; Giampieri et. al., 2022).

The key reserve of such agrotechnologies aimed at increasing the seed productivity of soybeans is the use of biological preparations that stimulate the activity of nitrogen-fixing and phosphorus-mobilizing bacteria, positively affecting the development of the root system and above-ground mass. It is also a guarantee of the formation of high, stable and high-quality crops, which will contribute to the provision of highly efficient and competitive production of soybean seed products (Poore et. al., 2019; Kuht et. al., 2016; Alaru et. al., 2014; Babich et. al., 1998).

The potential productivity of soybean seed products reaches its maximum at the moment of full maturity, after which it steadily, continuously and irreversibly decreases. The rate of reduction of potential seed productivity during seed aging is largely determined by the genetic characteristics of the variety, as well as environmental conditions before and during storage. These prerequisites establish variation between seed lots and even between individual seeds within the same lot. Therefore, the study of the issue of reduced germination is not only an important indicator of seed aging, but also an indicator of its future loss of viability (Petrychenko et. al., 2012; Nicholas et. al., 2021; Mazur et. al., 2020; Bakhmat et. al., 2023).

Soybean seeds belong to a group in which, when stored in seed warehouses in uncontrolled environmental conditions, seed germination is lost quite quickly. This is due to the presence of nutritious protein and oil, a hygroscopic seed coat that is easily damaged, which facilitates the access of air, moisture and pathogens of harmful objects. Trends have been established: the higher the storage temperature and seed humidity, the faster seed germination is lost. With the interaction of high temperature and humidity of seeds, favorable conditions are created for increased respiration and development of microbiota (Petrychenko et. al., 2018; Maxwell et. al., 2016). Thus, the economic durability of soybean seed production is an important aspect of plant life and, undoubtedly, is of considerable theoretical and practical interest for domestic seed production. The need to solve this scientific and topical issue conditioned the conduct of our research.

The basis of the scientific hypothesis is the idea of obtaining organic seed production of soybeans from organic agrophytocenoses due to the optimization of technological methods of cultivation, which ensures the improvement of fertility, structure and water regime of the soil, rational nutrition of plants and the nature of growth processes (Puyu et al., 2021; Petrychenko et. al., 2003). In this aspect, increasing the effi-ciency of the use of agricultural technologies aimed at increasing the seed productivity of soybeans is the use of biological preparations that stimulate the activity of nitrogen-fixing and phosphorus-mobilizing bacteria, positively influencing the development of the root system and above-ground mass.

Therefore, the determination of the optimal parameters for the use of bacterial preparations and foliar fertilizers in the pre-sowing treatment of seeds in varietal technologies of soybean cultivation in the right-bank forest-steppe zone of Ukraine is relevant both in practical terms and for the formation of the theoretical basis of programs for the development of highly effective adaptive technologies.

It was established that under such highly effective adaptive technologies, the enzymatic system of antioxidant protection is stimulated, which, in turn, leads to the stabilization of peroxide processes in soybean seedlings. According to many authors, one of the relevant elements of modern

technologies is the use of bacterial preparations for pre-sowing treatment of seeds. This stimulates the germination process, protects the seeds during their long-term stay in the soil from adverse conditions, increases the field germination of seeds, promotes the active development of the root system (Zhou et. al., 2020; Petrychenko et. al., 2012 a; Parizad et. al., 2021; Parga et. al., 2022), which is especially important in case of water deficit.

MATERIAL AND METHODS

Field experiments were laid on the fodder crop rotation fields of the Department of Legumes of the Institute of Fodder and Agriculture of the Podillia Branch of the National Academy of Sciences using the method of split plots in four repetitions according to the methodology of experimental work in agronomy. The effectiveness of complex inoculation on the sowing properties of soybean seeds was evaluated in laboratory and growing conditions. Laboratory experiments were carried out in accordance with the requirements of DSTU 4138-02 and generally accepted recommendations in Petri dishes (25 seeds per dish) in 4 repetitions per variant (100 seeds per variant) at a temperature of 22 °C under natural lighting and temperature regime in 5–6 times repetitions according to variants in 10-kilogram Wagner vessels on sand and soil substrate with Gelrigel nutrient mixture (0.25 norm of mineral nitrogen. The soils are gray podsolized, medium loamy in the forest, typical for the forest-steppe of the Right Bank and Vinnytsia regions, Ukraine. Agricultural techniques for growing soybean seeds in the experiments were generally recognized for the conditions of the right-bank forest-steppe of Ukraine (Table 1). Soybean varieties bred at the Institute of Feed Research and Agriculture of Podillya of NAAS served as material for research, namely Slavna, Churaivna, Azymut, Tytan, Triada, Pallada, Samorodok.

The aim of the research was to determine the sowing qualities of soybean seeds (varieties Slavna, Churaivna, Azymut, Tytan, Triada, Pallada, Samorodok), namely seed moisture, germination energy, field germination and linear hypocotyl parameters.

RESULTS AND DISCUSSION

Soybean cultivation in the conditions of the forest-steppe of Ukraine is becoming more and more relevant and requires refinement and improvement of varietal cultivation technology, in particular, due to adapted and plastic varieties to abiotic factors, bacteriization of seeds and nutrients. Therefore, in order to obtain a high yield, it is necessary to take the best fertile fields and predecessors under soybeans, sow high-yielding varieties, and master the adaptive varietal cultivation 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 (Patyka et. al., 2004; Hnatiuk et. al., 2019).

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

Table 1. Scheme of the experiment in the field conditions of the Institute of Feed Research and Agriculture of Podillya NAAN in the village of Bohonyky, Vinnytsia region, Ukraine

Factor A – varieties	Factor B – pre-sowing treatment of seeds
1. Slavna	1. Without pre-sowing seed treatment
2. Churaivna	2. Pre-sowing treatment of seeds with nitrogen-fixing bacteria (Rizolain+Rhizosev)
3. Azymut	3. Pre-sowing seed treatment with organo-mineral fertilizer HELPROST
4. Tytan	4. Pre-sowing treatment of seeds with nitrogen-fixing bacteria (Rizolain+Rhizosev)
5. TRIADA	
6. PALLADA	
7. SAMORODOK	

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 acreage occupied by soybeans is 2.2 million hectares, while the soil will receive the amount of nitrogen equivalent to 546,000 tons of ammonium nitrate worth more than UAH 1 billion (Fig. 1).

Seed moisture is an important factor determining the stability of seeds during long-term storage. For soybean seeds, humidity is more important and is the main storage condition. Limit-safe humidity indicators for soybean storage depend on the air temperature, mass of the batch, as well as on the direction of use. Increased humidity leads to the germination or development of mold, which is caused by an increase in temperature, as a result of which the quality of protein and oil deteriorates (Zhou et. al., 2020; Petrychenko et al., 2012b) Soy is a promising food crop in Ukraine, therefore the development of technological means of increasing its productivity is an urgent issue today. Plants are most sensitive to environmental factors during the phase of seed germination and seedling formation. The initial conditions for seed germination are crucial for the subsequent stages of plant growth, development and productivity. Under unfavorable conditions of seed storage (unregulated conditions outside granaries), its sowing properties deteriorate, the initial stages of plant development are inhibited. Sowing properties of seeds is one of the determining criteria for its implementation by agro-industrialists, therefore, evaluation and development of ways to improve the sowing properties of seeds of agricultural crops are relevant, especially when they are stored for several years (Pawlewicz et. al., 2020).

The laboratory analyzes shown in Figure 2 confirmed that the moisture content of soybean seeds during five years of storage in an

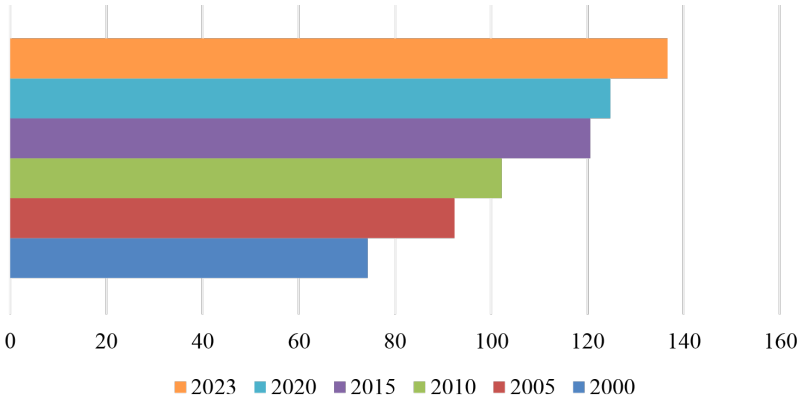

Figure 1. World soybean seed production per unit area by year, million hectares (average for 2000–2023)

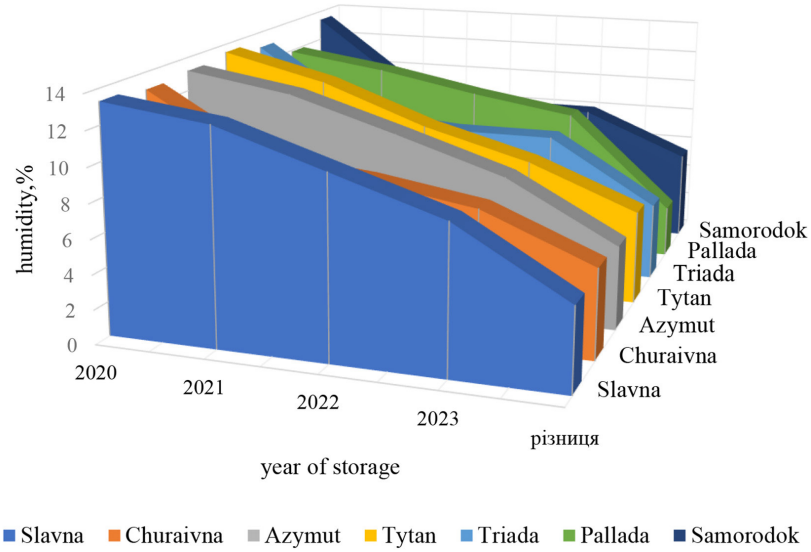

Figure 2. World soybean seed production per unit area by year, million hectares (average for 2000–2023)

uncontrolled climate was within the norm and did not exceed 13.4%. It was established that the highest humidity was observed in the first year of storage and varied depending on the variety from 11.9% to 13.5%. At the same time, during 2020–2024 storage, the largest moisture loss of soybean seeds among the studied samples was observed in the Tytan variety – 5.5%, and the smallest – in the Pallada variety – 3.1%, which is due to varietal characteristics (Hetman et. al., 2024; Zhou et. al., 2019; Ramakrishnan et. al., 2021) In varieties Slavna, Churaivna, Azymut, Triada, Samorodok, seed moisture decreased from the initial by 4.8%, 5.2%, 4.9%, 4.6% and 5.4%, respectively.

The analysis of experimental data proved that the germination energy of soybean seeds varied to a different extent under the influence of the researched technological methods of cultivation (Table 2). Analyzing the laboratory parameters during the treatment of soybean seeds, it was noted that the use of pre-sowing treatment of seeds with a bacterial preparation based on nodule bacteria strains in combination with foliar fertilization in the phases of budding and bean formation with organo-mineral fertilizer had a smaller effect on laboratory germination, and to a greater extent on the energy of germination soybean seeds The maximum indicator was obtained on the Slavna soybean variety – 93.4% for the use of nitrogen-fixing bacteria (Rizolain+Rhizosave) and organo-mineral fertilizer HELPROST in combination with foliar feeding in the phases of budding and bean formation with organo-mineral HELPROST in the pre-sowing treatment of seeds. The lowest germination energy was recorded in the control variants of the Samorodok variety – 74.6% According to the varietal composition, the advantage of the Svavna and Tytan varieties was revealed from the point of view of obtaining high germination energy. On these varieties, the investigated indicator had the maximum average factorial value.

In the conditions of the vegetation experiment, it was also shown that pre-sowing seed treatment promotes the germination of soybean seeds. The laboratory similarity had a significant tendency to increase to 96.3–98.1% in variants with Svavna and Tytan varieties for the use of nitrogen-fixing bacteria (Rizolain+Rhizosave) in the pre-sowing seed treatment (Table 3).

Table 2. Germination energy of soybean seeds depending on pre-sowing treatment, %

Pre-sowing treatment of seeds	Svavna	Churaivna	Azymut	Tytan	Triada	Pallada	Samorodok
Without pre-sowing seed treatment	81.1	80.6	80.4	80.8	80.3	79.3	74.6
Pre-sowing seed treatment with nitrogen-fixing bacteria (Rizolain + Rhizosev)	83.0	82.2	82.0	82.4	81.9	80.8	80.6
Pre-sowing treatment of seeds with organo-mineral fertilizer HELPROST	83.2	82.4	82.2	82.6	82.1	81.1	80.8
Pre-sowing treatment of seeds with nitrogen-fixing bacteria (Rizolain+Rhizosave) and organo-mineral fertilizer HELPROST	93.4	91.3	91.1	91.5	91.0	90.1	89.8

Table 3. Laboratory germination of soybean seeds depending on pre-sowing treatment, %

Pre-sowing treatment of seeds	Svavna	Churaivna	Azymut	Tytan	Triada	Pallada	Samorodok
Without pre-sowing seed treatment	76.5	76.2	75.9	76.4	76.6	76.4	75.3
Pre-sowing seed treatment with nitrogen-fixing bacteria (Rizolain + Rhizosev)	88.5	84.2	84.0	84.9	84.3	83.8	82.9
Pre-sowing treatment of seeds with organo-mineral fertilizer HELPROST	87.0	84.4	83.7	83.9	82.7	82.8	83.1
Pre-sowing treatment of seeds with nitrogen-fixing bacteria (Rizolain + Rhizosave) and organo-mineral fertilizer HELPROST	97.2	93.5	93.1	94.5	94.0	93.6	93.4

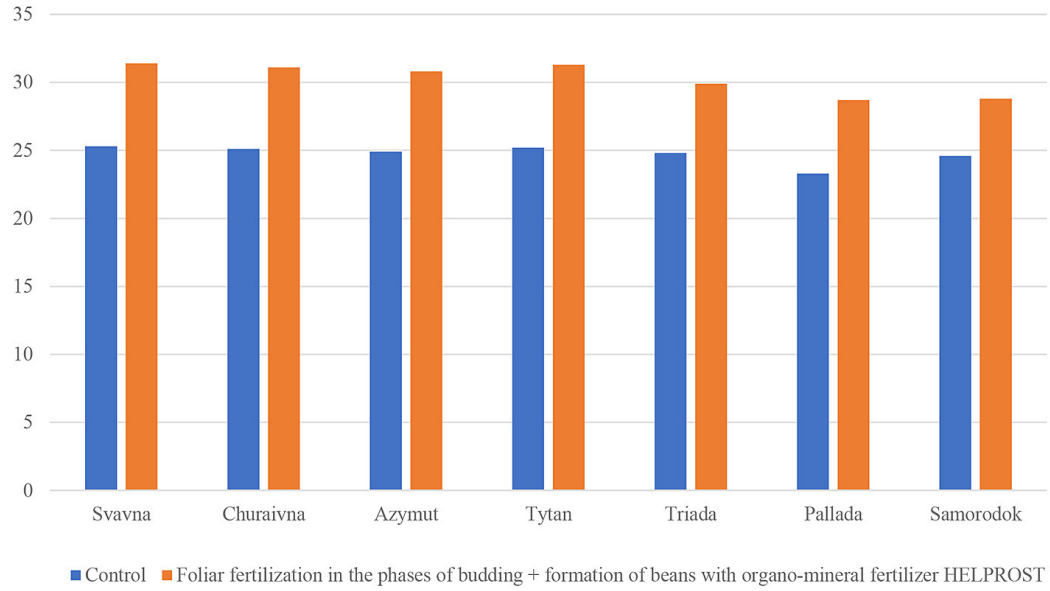

Figure 3. Linear parameters (length) of the hypocotyl, mm

The use of pre-sowing seed treatment can cause both positive changes in germinating seeds and reduce their laboratory germination and germination energy in case of overdose. In order to determine the optimal dose of application of drugs during seed treatment for the sowing quality of soybeans, a study was carried out on the linear parameters of the hypocotyl, the results of which are presented in Figure 3.

Therefore, according to the linear parameters of the hypocotyl, it was established that its length varied within 23.3–31.4 mm. The lowest linear values were recorded in the control plots. In the Pallada and Samorodok varieties, the linear parameters of the hypocotyl were 23.3 mm and 24.6 mm, respectively, on the water-treated variants (control), which is a genetically determined trait. According to the numerical values of the linear parameters of the hypocotyl, the highest indicators were recorded in the plots of the Slavna variety for the use of nitrogen-fixing bacteria (Rizolain + Rhizosev) and organo-mineral fertilizer HELPROST in combination with foliar fertilization in the phases of budding and bean formation with organo-mineral fertilizer HELPROST in the pre-sowing seed treatment.

CONCLUSIONS

In order to stimulate the emergence of soybean seeds from dormancy, including during their storage for several years in unregulated conditions, as well as the development of seedlings, the formation of vegetative mass of plants and symbiotic systems with increased functional capacity, it is necessary to apply pre-sowing treatment of seeds as a more effective measure than inoculation of seeds with a monoculture of plant-specific rhizobia. Pre-sowing treatment of seeds with a bacterial preparation in combination with trace elements should be considered as a significant additional element to the existing technology of soybean cultivation. This technological technique makes it possible to assert its positive effect on the growth and development of plants throughout the growing season, which ultimately affected the productivity of soybeans. The conducted laboratory analyzes established that the moisture content of soybean varieties during five years of storage in uncontrolled climate conditions was within the normal range and did not exceed 13.4%. Analyzing the laboratory parameters during the treatment of soybean seeds, it was noted that the use of pre-sowing treatment of seeds with a bacterial preparation based on nodule bacteria strains in combination with an organo-mineral fertilizer had a smaller effect on laboratory germination, and to a greater extent on the germination energy of soybean seeds. The maximum indicator was obtained on the Slavna soybean variety – 93.4% for the use of nitrogen-fixing bacteria (Rizolain+Rhizosave) and organo-mineral fertilizer HELPROST in the pre-sowing treatment of seeds. The laboratory similarity had a significant

tendency to increase up to 96.3–98.1% in variants with Svavna and Tytan varieties with the use of nitrogen-fixing bacteria (Rizolain+Rhizosave) and organo-mineral fertilizer HELPROST in the pre-sowing seed treatment.

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