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Physiological and biochemical aspects of pre-sowing treatment of soybean (*Glycine max* (L.) Merr.) seeds

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Abstract. Soybean is one of the most in-demand crops, with its production increasing; however, climate change affects yield, necessitating the application of biopreparations to enhance plant resilience to stress conditions. This study aimed to investigate the effects of pre-sowing seed treatment with an inoculant and a phytohormonal preparation on the physiological and biochemical parameters of

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soybean plants and their yield under organic farming conditions. A field study conducted in 2022-2024 examined the impact of pre-sowing seed treatment with the inoculant Legume Fix and the phytohormonal preparation Violar on leaf area, proline content, malondialdehyde levels, photosynthetic pigments, and yield under various weather conditions in an organic farming system. It was established that pre-sowing seed treatment increased leaf area by an average of 13.4% with Legume Fix and by 19.3% with Violar. It was established that the highest increase in proline content (as a protective response) was observed in the hot conditions of 2024, with seed treatment using Violar (41.2%) and Legume Fix (26.5%). Over the study period, the lowest MDA concentrations in soybean plants were recorded following seed treatment with Violar and Legume Fix, averaging 7.57 and 9.33 μg/g fresh weight, respectively, which was 37.4% and 22.9% lower than in the control plants. Treatment with Violar resulted in an increase in Chl *a*, Chl *b*, and total Chl (*a* + *b*) content by an average of 18.9%, 13.3%, and 17.2%, respectively, compared to the control, while inoculation with Legume Fix led to increases of 7.4%, 3.4%, and 6.2%, respectively. Pre-sowing seed treatment with Legume Fix and Violar resulted in a higher yield than the control plants, with average increases of 13.2% and 20.6%, respectively. The obtained results may be recommended for organic farming to enhance crop yield

Keywords: leaf area; proline; malondialdehyde; photosynthetic pigments; organic farming; weather conditions

Introduction

The study of the physiological and biochemical aspects of pre-sowing seed treatment is important for understanding the processes that occur in seeds during preparation for sowing, as it allows for the determination of optimal treatment methods to improve their germination energy, resistance to stress conditions, and increase yields. Such treatments can affect the biochemical processes that occur in seed cells, including enzyme activity, protein synthesis, and processes related to the energy supply of germination. Studying the physiological responses of seeds to treatment helps to develop effective technologies that stimulate plant growth and development, and improve their adaptation to adverse conditions such as droughts or low temperatures, which is particularly relevant in the context of climate change. This knowledge also makes it possible to reduce the use of chemical fertilisers and pesticides, which is important for sustainable agriculture and environmental conservation.

According to J. Bosanquet (n.d.), soybean (*Glycine max* (L.) Merr.) is one of the most soughtafter legume crops in the global market, which ranks it sixth among the most widespread crops in terms of production volume and fourth in terms of economic value and production area. This growth is accompanied by a 5% increase in global soybean consumption due to demand in the feed, food, and industrial sectors (IGS: Global soybean production in 2024/25 MY to break record, 2024).

In Ukraine, despite abnormal heat and drought in 2024, soybean production reached a record 6.0 million tonnes, an increase of 15.4% compared to 2023. Soybean production in the EU increased by only 0.3% compared to the previous year due to the negative impact of weather conditions in Central European countries (Ukraine soybean area, yield and production, n.d.). V. Voora *et al.* (2022) stated that in Europe, ongoing climate change and the high demand for genetically unmodified soybeans in domestic markets are contributing to the idea of introducing soybeans into typical organic farming systems. Considering the research of JJ.L. Rotundo *et al.* (2024), the EU market is the largest sales market for domestic soybeans (47% of total exports), so Ukrainian producers seek to adhere to the European Green

Deal, one of the important directions of which is the introduction of organic production.

According to research by M.B. Hrabovskyi *et al.* (n.d.), the profitability of growing organic soybeans in Ukraine is high, and although its yield is lower compared to traditional technology, lower production costs and a higher selling price make such production more profitable. At the same time, the presence of climatic risk, especially the uneven impact of precipitation and high temperatures, requires the introduction of technological innovations to increase its yield. However, it is difficult to obtain high yields and quality soybean seeds, despite the proper soil properties, even in organic farming conditions, due to water scarcity and prevailing high temperatures.

Scientists M.S. Hossain *et al.* (2024) noted that despite its adaptability, soybeans also face challenges from climate variability, including unpredictable precipitation patterns that threaten growth and yield. The degree of effect depends on when the period of high temperatures occurs and how intense the water deficit is. Such changes in weather conditions can cause a decrease in soybean yields of up to 40%. Research by A.C.S. Nakagawa *et al.* (2020) showed that when soybeans are exposed to high temperatures during the seed-filling stage, their yield decreases and the seed composition changes. Studies by L. Ogunkanmi *et al.* (2022) indicated that the most detrimental effect on soybean yield (a decrease of 42-64%) is the combined effect of high temperature and drought compared to their individual effects.

According to M.N. Khan *et al.* (2019), one of the promising directions for managing the process of forming stable agroecosystems of legumes, primarily soybeans, is the use of preparations that allow protecting the physiological state of plants from excessive temperature effects and precipitation deficits. According to research by I. Korotkova *et al.* (2023), the most commonly used technological measures at present are the priming of seeds with various biostimulants, hormonal preparations and osmoprotectants, which have already been tested on crops such as wheat, corn and chickpeas.

While there is plenty of research on the individual benefits of microbial and phytohormonal treatments for soybean seeds, there is less focus on comparing their effectiveness, especially in organic farming. Pre-sowing inoculation with bacterial preparations is a vital part of organic growing. According to S. Brambilla *et al.* (2022), various symbiotic and non-symbiotic rhizobacteria are used as bioinoculants to boost plant growth and development through mechanisms like nitrogen fixation, siderophore production, and phytohormone synthesis.

This study aimed to assess the role of pre-sowing inoculation and phytohormonal seed treatment in organic farming systems in mitigating the effects of extreme temperatures during the growing season by evaluating their impact on the physiological and biochemical parameters of plants and overall yield.

Materials and Methods

The field studies were conducted at the experimental field of Poltava State Agrarian University (Khudoliivka Village, Kremenchuk District, Poltava Region) during 2022-2024. The region is known for its ecological purity due to the nearby forest massifs and Sudebske Lake. The soil of the experimental plots is residual-saline chernozem on loess deposits with a moderate level of nitrogen and phosphorus availability and high potassium. For soil analysis, 5 samples were taken from a depth of 0-20 cm of the experimental plot. A composite soil sample was prepared by mixing the collected samples. The sample was air-dried, crushed, and passed through a 2 mm sieve. The content of nitrogen, phosphorus, potassium, and pH in the soil samples (0-20 cm) was determined using a Palintes SK500 multiparameter photometer: pH_{KCl} – 6.3; humus – 5.2%; total nitrogen – 58.6 mg/kg; phosphorus (P_2O_5) – 78.3 mg/kg; potassium (K_2O) – 138.4 mg/kg. The total area of the land plot was 0.3 ha, and the accounting area was 0.1 ha.

The experiments employed standard agricultural practices for the cultivation zone. Its predecessor was spring barley. Soybean sowing was carried out at optimal times according to the climatic conditions of the year of research to a depth of 5 cm, with a row spacing of 38 cm and a seeding rate of 700 thousand seeds/ha. The technological soil cultivation, taking into account the peculiarities of growing plant crops using organic technology, included autumn ploughing, spring harrowing with a heavy harrow to retain moisture, cultivation with a stubble implement, pre-emergence and post-emergence harrowing with a Striegel mesh harrow (Hatzenbichler, Austria), and two inter-row cultivations to control weeds. To protect crops from pests, trichogramma (100-200 thousand individuals/ha) was manually applied three times at 50 points per hectare: before sowing, one month later, and as needed, depending on the level of crop infestation.

The object of the study was the early-ripening soybean variety Khorol of Ukrainian selection, originator – Soybean Research Institute LLC. The experiment was repeated three times. The placement of variants was randomised. For soybean seed inoculation, the bacterial preparation Legume Fix (Legume Technology Ltd, United Kingdom) and the preparation with a complex of phytohormones Violar (Ukraine) were used. Seeds were inoculated using the dry method 30 minutes before sowing at a rate of 1.25 kg of inoculant per 500 kg of seeds. The biopreparation Violar was used for pre-sowing seed treatment (0.5 L/t) and for spraying during the budding-early flowering stage (10 mL/ha). In the control variant, soybean seeds and plants were treated with an equivalent amount of water. The content of proline and malondialdehyde (MDA) in soybean leaves was determined by the method of M.K. Fatema *et al.* (2017).

Optical density measurements were performed using a ULAB 108 UV spectrophotometer. The leaf area was calculated using the Easy Leaf Area software (Easlon & Bloom, 2023). Knowing the leaf area per plant and multiplying this by the plant density per hectare, the leaf apparatus area of plants per specific area was obtained, expressed in m^2/ha. The research was conducted following the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

Material for the determination of photosynthetic pigments was processed fresh immediately after collection. Pigments were extracted with 96% ethanol. Spectrophotometric measurement of the optical density of ethanol extracts for the determination of chlorophyll *a* (Chl *a*) and chlorophyll *b* (Chl *b*) content was carried out without prior separation at the absorption maxima of Chl *a* – 665 nm, Chl *b* – 649 nm using a ULAB 108 UV spectrophotometer (ULAB, China). The calculation of pigment content in the obtained extracts was carried out using the method of A.R. Wellburn (1994) according to formulas (1-2):

$$C_{\text{chl } a} = [(13.95D_{665} - 6.88D_{649}) \cdot V]/m, \quad (1)$$

$$C_{\text{chl } b} = [(24.96D_{649} - 7.32D_{665}) \cdot V]/m, \quad (2)$$

where $C_{\text{chl } a}$, $C_{\text{chl } b}$ are the concentration of Chl *a* and Chl *b* in mg/g of fresh weight; D_{665} and D_{649} are the optical density of the alcohol extract of pigments at wavelengths $\lambda = 665$ nm and $\lambda = 649$ nm, respectively; *m* is the sample weight, mg; *V* is the volume of ethanol, cm^3. MS Excel was used for the graphical display of the research results. The significance of the experimental data was assessed using analysis of variance (ANOVA) to calculate the least significant difference (LSD_{05}).

Results and Discussion

An analysis of the dynamics of soybean leaf area formation during 2022-2024 allowed for an assessment of the impact of weather conditions during the crop's growing season (Fig. 1).

The provided data shows that in 2022 and 2023, temperature and moisture levels were more favourable for soybean growth and development. However, in 2024, excessively high temperatures and low relative air humidity were observed due to insufficient atmospheric precipitation and uneven distribution throughout the growing season, which limited the leaf area formation of the crop.

In the hot year of 2024, the leaf area of soybean plants was lower than in the previous years, 2022 and 2023, for all experimental variants (Fig. 2): 16.5-22.1% lower in the control; 13.6-21.3% lower with Legume Fix inoculation; and 16.1-21.2% lower with Violar phytohormonal treatment. In the current studies, the proline and MDA content were used as stress biomarkers, the overcoming of which was facilitated by the use of Legume Fix inoculant and Violar phytohormonal preparation (Fig. 3).

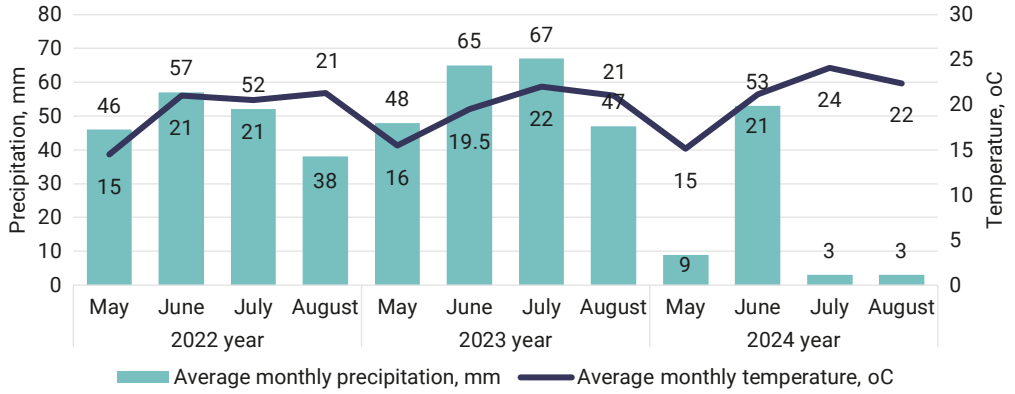

Figure 1. *Average monthly air temperature and precipitation during the soybean growing season*
Source: compiled by the authors

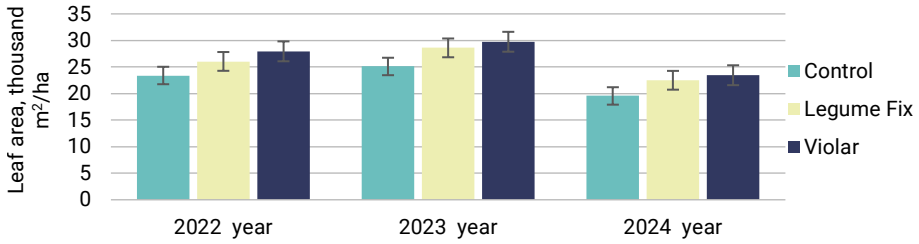

Figure 2. *Dynamics of leaf area formation of soybean plants of the Khorol variety under different pre-sowing treatment technologies, thousand m²/ha*
Note: average for 2022-2024
Source: compiled by the authors

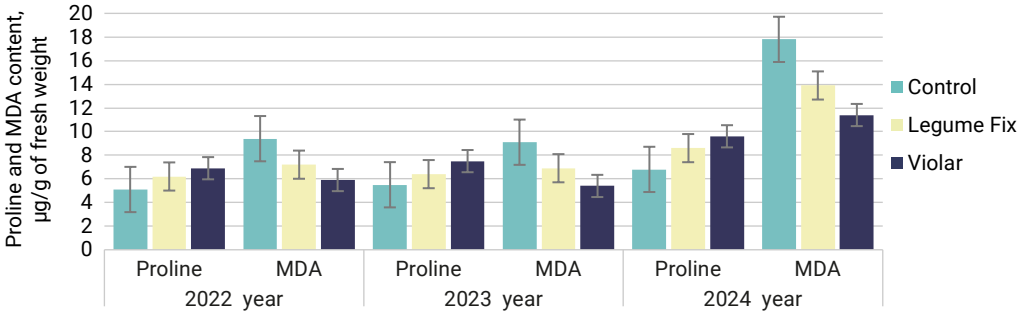

Figure 3. *Proline and MDA content in soybean plants of the Khorol variety under different presowing treatment technologies, µg/g of fresh weight*

Source: compiled by the authors

The proline content in plants in the control was the lowest for all years of research. Indicators of high temperature in 2024 correlated with the maximum proline content (9.6 μg/g of fresh weight); when seeds were treated with the phytohormone Violar, the proline content increased by 41.2% and 26.5% when inoculated with Legume Fix compared to the control. Soybean plants grown in more favourable weather conditions in 2022-2023 also had increased proline content, but the excess over the control when treated with Violar averaged ~22.6% and with Legume Fix ~18.7%. Control plants showed the highest MDA content, indicating the level of response to oxidative stress compared to other treatments (Fig. 3). Soybean plants grown from treated seeds were more resistant to adverse temperature conditions due to a decrease in MDA levels. The MDA content in plants treated with the phytohormone Violar was lower than the content in control plants by ~36% and with Legume Fix inoculation by ~22% in 2024, which differed from previous years with extremely indicators of high temperature with moisture deficit during the growing season.

In 2022-2023, the lowest concentration of MDA in soybean plants was observed when seeds were treated with Violar, with the MDA concentration averaging ~5.65 μg/g of fresh weight, which is 38.9% less than the MDA content in control plants. Legume Fix inoculation also showed an effective action in overcoming temperature stress; the MDA content in plants decreased to an average of ~7.05 μg/g of fresh weight, which is ~23.8% less than in control plants. Therefore, priming soybean seeds with Violar demonstrates better results compared to the effect of Legume Fix. The level of MDA in plants from seeds treated with Violar was almost 20% lower relative to the MDA level with Legume Fix treatment in 2022-2023 and 18% in 2024. A significant increase in proline levels in plants was observed as a result of treating soybean seeds with Violar and Legume Fix. This protective response was absent when seeds were treated with water (control), where the lowest proline levels were recorded for all years of research.

To determine the effect of pre-sowing seed treatment with Legume Fix and Violar on the functioning of the photosynthetic apparatus of soybean plants under different weather conditions, an analysis of the dynamics of chlorophyll Chl *a* and Chl *b* content was performed, and the sum of their forms was calculated since the efficiency of the pigment system affects the yield of soybean crops and depends on environmental conditions (Table 1).

Table 1. *Chlorophyll a and b content in leaves of the Khorol soybean variety at the flowering stage depending on pre-sowing treatment technology*

Technology	Chl *a*			Chl *b*			Chl (*a* + *b*)		
	2022	2023	2024	2022	2023	2024	2022	2023	2024
Control (water)	1.12	1.17	0.78	0.46	0.48	0.34	1.58	1.66	1.12
Legume Fix	1.17	1.23	0.88	0.47	0.49	0.36	1.64	1.73	1.24
Violar	1.29	1.44	0.93	0.51	0.56	0.38	1.80	2.00	1.30
LSD_{05}		0.098			0.034			0.134	

Note: average for 2022-2024
Source: compiled by the authors

In the current study, pre-sowing treatment of soybean seeds with the experimental preparations improved the physiological parameters of plants and promoted an increase in chlorophyll content, which activated the photochemical functions of chloroplasts, increasing the efficiency of photosynthesis. The data in Table 1 shows an increase in the total Chl (*a* + *b*) content using Legume Fix and Violar, depending on the years of research, compared to the control by 3.510.7

and 14.1-21.0%, respectively. The total Chl (*a* + *b*) content in soybean plants using Legume Fix and Violar compared to control plants in 2024 increased by 10.7 and 16.1%, respectively, while in 2022-2023, it increased by an average of 4.0 and 17.5%, respectively. A comparison of the concentration of Chl *a* and Chl *b* in plants grown from seeds treated with Violar showed their maximum level in all years of research. The content of Chl *a* and Chl *b* exceeded the control by an average of 18.9 and 13.3%, respectively, and by 7.4 and 3.4%, the content of chlorophylls in plants from seeds inoculated with Legume Fix.

It should be noted that the content of photosynthetic pigments in the leaves of soybean crops in the more favourable year of 2023 increased, which may be due to the treatment of seeds with biological preparations. Thus, in 2023, compared to 2022, when using Legume Fix and Violar, an increase in Chl *a* content was observed by 5.1% and 11.6%, respectively, and the excess over the control was 5.1-23.1% under the action of both preparations. The increase in Chl *b* content in 2023 compared to 2022 correlated with an increase in Chl *a* levels. The concentration of Chl *b* in soybean leaves when using Violar was higher than its concentration in 2022 by 9.8%; the concentration of Chl *b* when using Legume Fix exceeded this indicator and the control by 4.3%. Despite a decrease in Chl *a* and Chl *b* content in all research variants in 2024, when plant growth was inhibited by high temperature. Compared with the content in plants grown in previous years, when using Violar, the Chl *a* content increased relative to the control by 19.2%, which confirms the effectiveness of its action in overcoming the temperature factor. However, the Chl *b* content when using Violar exceeded control plants in 2024 by 11.8%, and in the more favourable years of 2022-2023 – by 10.9-16.7%. When soybean seeds were inoculated with Legume Fix in 2024, the Chl *a* content in plants increased most significantly – by 12.8%, and Chl *b* – by 5.9% relative to control plants. A similar correlation was observed in 2022-2023 – the increase in Chl *a* was 4.5-5.1%, and Chl *b* only 2.1%.

Soybean yield in the control variant was determined at the level of 1.9-2.4 t/ha depending on the year (Fig. 4), while using Legume Fix and Violar – 2.1-2.8 and 2.3-3.0 t/ha, respectively. The experimentally determined increase in Chl (*a* + *b*) content relative to the control by 5.5% with Legume Fix inoculation and by 17.2% with the use of Violar phytohormonal preparation led to an increase in soybean yield by an average of 13.2-20.6%. At the same time, a direct correlation with a strong relationship was determined between the Chl (*a* + *b*) content and yield for all research variants: control – r = 0.986, when using Legume Fix inoculant – r = 0.983, Violar biopreparation – r = 0.988.

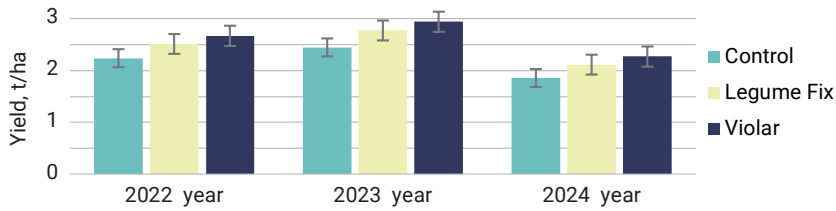

Figure 4. *Dynamics of soybean yield of the Khorol variety with pre-sowing seed treatment using different technologies, t/ha*

Note: average for 2022-2024

Source: compiled by the authors

The yield increase obtained in the current study correlates with the results of V. Tsygankova *et al.* (2017) – the use of Violar in the cultivation of spring wheat contributed to an increase in Chl *a*, Chl *b* and Chl (*a* + *b*) content by 20.0, 40.0 and 19.2%, respectively, which contributed to an

increase in grain yield by 20.3%. According to the results of the present research, the use of Violar led to an increase in Chl *a*, Chl *b* and Chl (*a* + *b*) content relative to the control by an average of 18.9, 13.3 and 17.2%, and yield – by 20.6%.

The effectiveness of the Legume Fix application is reflected in the study by H.L. Hadzovskyi *et al.* (2020), where inoculated soybean seeds were supplemented with foliar feeding of complex chelated micronutrients. As a result, the increase in Chl *a*, Chl *b* and Chl (*a* + *b*) content in the leaves of plants of two soybean varieties was 5.8-8.2, 1.1-16.8 and 6.8-7.8%, respectively, and yield – by 6.0-8.0%. According to research by T.O. Chaika *et al.* (2023), the use of Legume Fix in organic farming contributed to an increase in soybean seed yield by 12.4-16.1%, and according to S.S. Nimenko & M.B. Grabovskyi (2023), by 14.8-22.2%. The authors D.B. Lobell & G.P. Asner (2003) proved that with each 1°C increase in temperature, soybean yield decreases by an average of 17%. A. Puteh *et al.* (2013) and K. Jumrani & V.S. Bhatia (2018) note that high-temperature stress during mid-reproductive growth is more detrimental to crop and seed size than that occurring at early or late stages of reproductive development.

Bacterial preparations play a strategic role in mitigating the harmful effects of reactive oxygen species (ROS) through the production of various phytohormones that provide plant resistance. The result of inoculation depends primarily on the strains of bacteria included in the preparations and weather conditions. According to a study by M.S. Sheteiwy *et al.* (2021), inoculation of soybean seeds with *Bradyrhizobium* led to a decrease in ROS levels by an average of ~15% and an increase in proline content by ~20% compared to the control.

Oxidative damage caused by adverse temperature conditions can be reduced by inoculation with phyllosphere bacteria, strains of *Bacillus amyloliquefaciens*, *Azospirillum brasilense*, *Rhizobium leguminosarum*, *Mesorhizobium cicero*, *Trichoderma* sp., which form colonies in root zones and enhance plant growth under various circumstances, as was shown in rice plants (Seleiman *et al.,* 2021; Mokrienko *et al.*, 2024).

However, there are suggestions that bacterial preparations might be less effective under high temperatures. However, microorganisms do not necessarily die under the influence of high temperatures; they can enter a dormant state. Rehydrating dry soil promotes the stimulation of bacterial growth and the activation of respiration, as reflected in studies by P. Iovieno & T. Baath (2008) and A. Meisner *et al.* (2015).

Articles by X. Zhang *et al.* (2013) and M. Cardarelli *et al.* (2022) have shown that bacterial inoculation can positively affect the maintenance of photosynthetic pigments in plants under conditions of insufficient moisture. Seed bacterization contributes to an increase in Chl (*a* + *b*) content, which is explained by a direct relationship between chlorophyll concentration in leaves and nitrogen fixation intensity, which significantly depends on the symbiotic properties of nodule bacteria that determine plant nitrogen nutrition. According to research by O. Lastochkina *et al.* (2020), the use of *B. subtilis* induced an increase in Chl *a* and Chl *b* levels up to 1.52 and 1.46 times, respectively, compared to non-inoculated seeds due to an increase in proline levels, which provides neutralisation of ROS production in plants under drought conditions. At the same time, C. Pagano & M. Miransari (2016) and E. Yusnawan *et al.* (2019) proved that depending on the strain used, different results can be obtained regarding soybean development and yield.

According to research by S.G. Jaybhaye *et al.* (2024) and A. Koziuchko *et al.* (2024), presowing treatment of seeds with biologically active substances (phytohormones, vitamins, amino acids, etc.) plays an important role in increasing soybean productivity. Biologically active substances create a favourable microbiological and biochemical environment around germinating seeds, which stimulates growth, increases the resistance of seedlings to adverse weather conditions, and also activates beneficial soil microflora W.F. Abobatta & D.K.A. Al-taey (2023). When

growing common beans (*Phaseolus vulgaris* L.) under drought conditions, seed inoculation with *Bacillus velezensis* and foliar treatment with acetylsalicylic acid significantly increased Chl *a* levels by 25.5% and Chl *b* by 37%, which increased yield by ~30% compared to plants without inoculation (Zamani *et al.*, 2024).

Thus, the highest levels of Chl *a* and Chl *b* can be achieved under conditions of combined use of bacterial preparations in pre-sowing seed treatment and phytohormonal preparations, which indicates the possibility, within certain limits, of managing the photosynthetic process in legume crops. Thus, the experimental results and subsequent analysis highlight the phytohormonal preparation Violar as an effective means for inducing soybean plants to overcome adverse climatic conditions and form high yields under organic farming technologies.

Conclusions

In organic farming, inoculating seeds with bacterial preparations and priming them with phytohormone-containing substances significantly impacts soybean development and yield under harsh growing conditions (high temperatures and lack of precipitation). Quantifying parameters like leaf area and chlorophyll content, based on growing conditions and pre-sowing seed treatment, provides valuable insight into yield-boosting factors. Also, measuring MDA and proline levels when using these treatments helps assess their role in enhancing plant resilience to adverse weather.

The results showed that all methods of soybean seed treatment led to an increase in leaf area, photosynthetic pigment content, and their total while reducing MDA levels and increasing proline content. However, pre-sowing treatment with the Violar phytohormonal preparation was more effective than the Legume Fix bacterial inoculant. The MDA content in plants grown from Violartreated seeds was almost 20% lower in 2022-2023 and 18% lower in 2024 than after using Legume Fix. A significant increase in proline levels was observed both with Violar treatment (averaging ~40% relative to the control) and with Legume Fix inoculant use (~22%). The content of chlorophylls Chl *a* and Chl *b* in plants whose seeds were treated with Violar exceeded the control by an average of 18.9% and 13.3%, respectively, while with Legume Fix inoculation, these indicators increased by 7.4% and 3.4%. The experimentally established increase in the total chlorophyll content Chl (*a* + *b*) relative to the control by 5.5% when using Legume Fix and by 17.2% with Violar treatment, which contributed to an increase in soybean yield by an average of 13.220.6%.

A statistically confirmed strong direct relationship between these indicators and yield, which on average increased relative to the control by 13.2% (2.47 t/ha) when using Legume Fix and 20.5% (2.63 t/ha) when using Violar. This study demonstrates the possibilities of various approaches to soybean seed preparation (using bacterial and phytohormonal preparations) for cultivation using organic farming technologies, comparing their effectiveness. Future research is planned to be devoted to assessing the effect of their combined use in overcoming inevitable climate changes that pose a serious threat to soybean production and the development of effective adaptation measures.

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Conflict of Interest

None.

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Фізіолого-біохімічні аспекти передпосівної обробки насіння сої (*Glycine max* L. Merr.)

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Анотація. Соя є однією з найбільш затребуваних культур, і її виробництво зростає, але зміни клімату впливають на врожайність, що вимагає впровадження біопрепаратів для підвищення стійкості рослин до стресових умов. Мета роботи полягала у дослідженні впливу передпосівної обробки насіння сої інокулянтом і фітогормональним препаратом на фізіолого-біохімічні показники рослин і їх врожайність в умовах органічного землеробства. У польовому дослідженні, проведеному в 2022-2024 роках, проаналізовано вплив передпосівної обробки насіння сої інокулянтом Legume Fix та фітогормональним препаратом Віолар на площу листкової поверхні, вміст проліну, малонового діальдегіду та фотосинтетичних пігментів і врожайність в умовах органічного землеробства за різних погодних умов. Встановлено, що за передпосівної обробки насіння збільшується площа листкової поверхні в середньому на 13,4 % за використання Legume Fix і на 19,3 % – за обробки Віолар. З'ясовано, що найбільше підвищення проліну в рослинах (як захисна функція) спостерігалось у спекотному 2024 році за обробки насіння сої Віолар (41,2 %) та Legume Fix (26,5 %). За роки досліджень у рослинах сої спостерігали найменшу концентрацію MDA за обробки насіння Віолар і Legume Fix - в середньому 7,57 і 9,33 мкг/г сирої маси, відповідно, що на 37,4 і 22,9% менше, ніж в контрольних рослинах. За обробки Віолар вміст Chl *a*, Chl *b* і Chl (*a* + *b*) перевищував контроль у середньому на 18,9; 13,3 і 17,2 %, відповідно, а за інокуляції Legume

Fix – на 7,4; 3,4 і 6,2 % відповідно. Визначено, що за передпосівної обробки насіння сої Legume Fix і Віолар отримано більшу врожайність відносно контрольних рослин в середньому на 13,2 і 20,6 % відповідно. Отримані результати можуть бути рекомендовані для органічного землеробства з метою підвищення врожайності культури

Ключові слова: площа листкової поверхні; пролін; малоновий діальдегід; фотосинтетичні пігменти; органічне землеробство; погодні умови