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INFLUENCE OF HYDROTHERMAL CONDITIONS, SEED TREATMENT AND EXTRA-ROOT NUTRIENTS ON THE GROWTH AND DEVELOPMENT PHASES OF SOYBEAN PLANTS

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The article presents a study on the development of technological techniques for growing soybeans depending on hydrothermal conditions, seed treatment and foliar fertilization for the passage of plant growth and development phases. The relevance of the work is strengthened by the tasks of applied research, which is carried out at the expense of the state budget on the topic: «Development of ecologically oriented technologies for growing bioenergy crops to ensure energy independence and soil conservation for the formation of climate neutrality». The purpose of the work is due to the need to develop and substantiate biological elements of soybean cultivation technologies. This includes the formation and provision of their sustainable production, taking into account the biological requirements of plants to the hydrothermal conditions of the region. There is also a need to modernize individual technological methods and optimize their complex action in the technological cycle of soybean cultivation. The material of the research was soybean varieties of domestic selection – Madison and Diadema Podillia. Based on the phenological observations of the growth processes and development of soybean plants, it can be concluded that both the duration of the periods between individual phases of growth and development, and the duration of the growing season as a whole, were significantly influenced by the hydrothermal conditions of the year, as well as organized factors that were put to study, namely seed inoculation and foliar fertilization. It was determined that for optimal parameters of swelling and germination, soybean seeds need 140-160% of water by weight. Soybean seedlings are severely depressed when there is a lack of moisture. Therefore, the first critical period for moisture supply in soybeans occurs in the branching phase, and the second is more intensive – in the phase of seed formation and pouring. The most favorable conditions for growth, development and optimal passage of interphase periods by soybean plants were determined when growing them in experimental variants, where seed inoculation was carried out with the preparation Bio-inoculant BTU (2 l/t) in combination with foliar fertilizing with organo-mineral fertilizer Helprost soy (2.5 l/ha).

Key words: *soybean, variety, pre-sowing seed treatment, foliar fertilization, critical periods, interphase periods.*
Table 2. Lit. 13.

Problem setting. Abiotic factors have a significant impact on the processes of growth, development and productivity of agricultural crops, including legumes. These include various elements of the environment that are not living, but significantly influence biological processes. Among these factors, the soil and climatic conditions of a specific growing area play a special role [1].

Soil conditions include aspects such as texture, fertility, moisture content, pH, and trace elements that directly affect nutrient availability to plants. Quality soil provides optimal conditions for the development of the root system, which is key for all types of plants. Climatic conditions, in turn, include temperature, rainfall, air

humidity, and solar activity, which form the general picture of growing crops in a certain region [1-2].

These factors directly determine the occurrence of limiting factors in the region, such as droughts, flooding, lack or excess of certain nutrients, which can negatively affect the growth and development of plants. That is why it is important to adjust the technological methods of growing for effective management of the production process, providing plants with everything necessary for their healthy development [2].

Therefore, a detailed analysis of soil cover characteristics and climate changes in the cultivation area allows not only to assess the current conditions, but also to predict possible difficulties that may arise in the cultivation process. This knowledge enables agronomists and farmers to develop adaptive strategies that contribute to the formation of a stable and highly productive system of growing legumes, which in turn ensures food security and economic stability in the region [3-4].

Analysis of research and publications. The analysis of scientific works, as well as a significant amount of historical-scientific, biographical and popular scientific literature [5-6] confirms that the study of technological methods of growing soybeans depending on hydrothermal conditions, seed treatment and foliar feeding at various stages of plant growth and development is a topical topic not only for Ukraine, but also in a global context. This issue has become the object of scientific research at the international level, since the efficient cultivation of soybeans is important for food security, economic development and sustainable agriculture in many countries of the world. Research in this field contributes to the optimization of agricultural technologies, increasing the yield and quality of products, as well as the adaptation of agriculture to changing climatic conditions [5].

According to the analysis of the scientific literature, a variety of technological methods of soybean cultivation were studied, which are aimed at the rational use of natural agricultural potential. Therefore, according to Hanna Pantsyreva, certain components of technological methods are an important agromeasure that can restrain the further decrease in soil fertility and stabilize the production of soybean seeds [1, 6, 7, 9]. It was established that in the variants where the bacterial preparation Rhizogumin-Plus was used for pre-sowing seed treatment and two-time spraying of plants with a 0.75% retardant solution during vegetation (phases of the 3rd trifoliate leaf and budding) an improvement in the complex of economic and valuable traits was obtained (crude protein content and fat) and productivity of soybean seeds.

This, in turn, will help to increase the sown areas of the main high-protein plants, which have an important strategic importance. The effective implementation of such technologies will not only increase the yield of soybeans, but also ensure a stable supply of protein products necessary for the nutrition of the population and the development of animal husbandry. Thus, the study of soybean cultivation technologies is of great importance for improving food security and sustainable development of the agricultural sector [1, 6].

When assessing the resource base on the basis of the State Register of Plant Varieties of Ukraine, the available range of soybeans was determined. Madison and Diadema Podillia soybean varieties were used in the study [10].

Research material and methods. Field studies on the influence of biological preparations and fertilizers of different mechanisms of action on soybean productivity were conducted at the experimental field of the Vinnytsia National Agrarian University, which is located in the central part of the Vinnytsia region. The topography of the experimental field is flat, the soil type is gray forest, the grain size is medium-loamy, the structure is lumpy, the density is 1.35-1.4 g/cm^3, the depth of the plowed soil layer is 30 cm. According to morphological characteristics, physical and in terms of physical and chemical indicators, they are typical for the Vinnytsia region and in general for the Right Bank Forest-Steppe [8, 12].

The scheme of the experiment included the following factors: Factor A – seed treatment: 1. No treatment; 2. BTU bioinoculant (2 l/t); 3. Risoline (2 l/t) + Rizosev (2 l/t); 4. Anderiz (1.5 l/t). Factor B – foliar feeding: 1. Without feeding (Control); 2. Biocomplex BTU (1.0 l/ha); 3. Gumifrend (1.0 l/ha); 4. Helprost soybean (2.5 l/ha).

According to various statements, soybean seeds need 140-160% of water by weight for optimal swelling and germination parameters. Soybean seedlings are severely depressed when there is a lack of moisture. The first critical period for moisture supply in soybean occurs in the branching phase, and the second – more intensive – in the phase of seed formation and pouring (Table 1).

Table 1

The necessary parameters of the temperature and water regime in the main periods of growth and development of soybean plants

Period of growth and development of soybeans	Air temperature, °C			Amount of moisture, m^3/ha
	min	max	optimal	
Sowing seedlings	8–10	15–18	20–22	15–30
Ladder-branching	10–12	17–20	22–25	15–30
Flowering	16–18	19–21	22–25	40–60
Formation of beans	13–14	17–18	20–23	40–60
Maturation	7–8	13–16	18–20	30–40

source: formed on the basis of own research

When growing soybeans, along with the level of moisture, temperature is an important factor in the formation of high crop productivity. Modern soybean varieties are classified according to the required sum of active temperatures (t > 10 °C). So, for a group of very early varieties, the sum of active temperatures should be within 1600-1900 °C, early ripening – 2000-2200, medium late ripening – 2800-2950 and late ripening – 3000-3200 °C. Thus, it can be concluded that the sum of active temperatures is one of the decisive factors in the selection of varieties for a specific region. So, the hydrothermal conditions of the place where soybeans are grown are a determining factor in obtaining high productivity. The analysis of hydrothermal

conditions during the years of research was carried out on the basis of meteorological data of the Vinnytsia Regional Center of Hydrometeorology. Hydrothermal conditions during the years of research were generally quite favorable for the growth and development of plants, however, in some years there were significant deviations from the long-term indicators, which in turn was reflected in the productivity of crops. The purpose of the work is due to the need to develop and substantiate biological elements of soybean cultivation technologies.

The relevance of the article is strengthened by the task of applied research on the topic: «Development of scientific and technological support for increasing soil fertility and rational use of the potential of biological resources» (state registration number: 0124U000444).

Research results and their discussion. The duration of the growing season of soybean varieties directly depends on the interaction of external meteorological factors with the biological features of plant development. This period is affected by several key conditions, including temperature regimes, lighting of crops and availability of sufficient moisture. For example, an insufficient amount of heat in combination with high humidity can lead to a lengthening of the growing season, as plants need more time for full development. At the same time, dry and warm weather significantly shortens the duration of this period. Increased air temperature also contributes to the reduction of the interphase period – from sowing to germination and from germination to flowering, which can affect the overall yield and product quality. Thus, consideration of these meteorological factors is important for optimizing soybean cultivation technologies.

The most favorable conditions for obtaining high soybean yields are formed when 300-350 mm of precipitation falls during the growing season, as well as when the set of active temperatures is within 2000-2500 °C. It is important to note that the productivity of this crop depends not only on the absolute level of hydrothermal resources, but also on their distribution during the growing season, especially during the critical stages of plant growth and development. The optimal combination of moisture and heat during these key periods can significantly affect crop formation, ensuring maximum soybean productivity. Therefore, effective management of water resources and monitoring of temperature conditions are critical for achieving successful results in the cultivation of this crop [2, 11, 13].

Soybean sowing, during the years of research, was carried out in the third decade of April. Based on the results of the research, it was established that both the total duration of the growing season and its individual periods directly depended on the pre-sowing treatment of seeds, foliar fertilizing and conditions of moisture supply and hydrothermal regime of the year. It was established that when favorable hydrothermal conditions were formed, soybean plants developed optimally, and the duration of the vegetation period corresponded to the maturity group of the studied variety, however, in the conditions of dry years, its duration changed. On average, over the years of research, the duration of the soybean vegetation period ranged from 110 to 118 days, while the longest vegetation period was recorded on the

experimental variants, where seeds were inoculated with BTU Bioinoculant and two foliar feedings were carried out in phase 3 – the third leaf and budding Helprost soybean. In the variants of the experiment, where only pre-sowing inoculation of seeds was carried out, the growing season lasted 112-113 days, while in the control variant the duration of the growing season was 110 days, respectively. The analysis of the duration of interphase periods in the section of the experimental variants showed that the period from sowing to full germination in the control variant lasted 16 days, and in the experimental variant, where pre-sowing inoculation of seeds with the preparation Bioinoculant BTU was carried out, seedlings appeared 2 days earlier than in the control. When seeds were treated with Anderiz or Rizolain + Rizosev composition, seedlings appeared 1 day earlier compared to the control.

The period from germination to the formation of the third trifoliate leaf, on average over the years of research, lasted 23 days in the control, in the variants where pre-sowing inoculation of seeds with the BTU Bioinoculant was carried out for 21 days, and 22 days with the inoculants Anderiz and Risoline + Rhizosev, respectively.

The period from the appearance of the third trifoliate leaf to mass flowering was characterized by intensive linear growth of soybean plants and the formation of its vegetative organs, which required a significant amount of moisture and heat.

After passing the vegetative stages of growth and development, during which the main vegetative mass of plants is formed and generative organs are laid, then the reproductive stages of development occur, which last from flowering to full ripening of seeds. It is known that the critical period for providing moisture for soybean plants is the flowering period. Over the years of our research, this period was characterized by elevated temperatures and varying amounts of precipitation. Thus, in 2017, the indicators of GTK for this period were 0.55, in 2018 – 0.91, in 2019 – 0.65, and in 2020 and 2021, respectively, 0.41 and 0.73. It was noted that foliar feeding of soybean plants, carried out in the phase of the third trifoliate leaf and full flowering, had a positive effect on the duration of the generative growth period and extended it (Table 2).

Starting from the flowering phase, soybean plants reacted more intensively to the studied factors. On the variants where foliar fertilization was carried out with helprost-mineral fertilizer Helprost Soya (2.5 l/ha) against the background of inoculation with the preparation Bioinoculant BTU (2 l/t), the flowering period lasted – 28±3.6 days, which is 3 days more compared to with areas where foliar fertilization was not carried out and for 6 days - compared to the control. A similar dependence was recorded against the background of other studied inoculants. So, on the variants where inoculation was carried out with the preparations Rizolain (2 l/t) + Rhizosev (2 l/t), the flowering period was 23±2.5 days, for foliar fertilizing with the biological preparation Biocomplex BTU (1 l/ha) and complex fertilizer for on the basis of Gumifrend potassium humate (1 l/ha), this period was extended to 25±2.8 and 24±2.7 days, respectively, the maximum duration of the flowering period of 26±3.0 days was noted when using the plow-mineral fertilizer Helprost Soya

Table 2

Duration of interphase periods of soybean plants depending on seed inoculation and foliar feeding, days, M±m*

Seed processing	Foliar feeding *	Sowing – full ladder	Complete stairs – third tripartite leaf	The third tripartite leaf is the beginning of flowering	Flowering	The end of flowering is full pouring of seeds	Full pouring of seeds – full ripeness	Full growth means full maturity
No processing	1	16±0,9	23±2,7	22±1,6	22±2,2	29±1,9	13±1,8	110±3,7
	2	16±0,9	23±2,7	21±1,1	23±2,3	30±1,9	14±1,8	112±3,3
	3	16±0,9	23±2,7	21±1,6	23±2,4	30±2,2	14±1,3	111±4,2
	4	16±0,9	23±2,7	20±1,5	24±2,5	31±1,8	15±1,9	113±3,9
BTU bio-inoculant	1	14±1,3	21±3,2	20±1,1	25±2,6	32±2,3	14±1,5	113±3,3
	2	14±1,3	21±3,2	19±1,1	27±3,2	34±2,2	15±1,7	117±4,0
	3	14±1,3	21±3,3	20±1,3	26±3,0	33±2,6	15±1,6	115±4,1
	4	14±1,3	21±3,3	19±1,3	28±3,6	35±1,8	16±1,7	118±4,3
Risoline + Risosave	1	15±0,7	22±2,5	21±1,1	23±2,5	32±2,1	14±1,6	112±2,9
	2	15±0,7	22±2,5	20±1,1	25±2,8	33±1,9	15±1,6	115±3,3
	3	15±0,7	22±2,5	20±1,1	24±2,7	32±1,5	14±1,7	114±3,2
	4	15±0,7	22±2,5	20±1,1	26±3,0	33±1,9	15±1,6	115±3,6
Anderiz	1	15±0,7	22±2,9	21±1,1	24±2,6	32±1,9	14±1,6	112±2,5
	2	15±0,7	22±2,9	20±1,1	25±3,0	33±1,9	15±1,6	115±2,9
	3	15±0,7	22±2,9	20±1,5	24±2,8	32±1,8	15±1,3	113±2,9
	4	15±0,7	22±2,9	20±1,1	26±3,0	33±1,5	15±1,6	115±3,0

*Note: *M ± m is the confidence interval of the arithmetic mean at the 5% level of significance. 1. without feeding (control); 2. Biocomplex of BTU; 3. Gumifrend; 4. Helprost soy.*

Source: formed on the basis of own research

(2.5 l/ha). With the use of Anderiz inoculant and foliar top dressing, the duration of the flowering period was the same as when using Risoline (2 l/t) + Rhizosev (2 l/t).

A similar trend was recorded during the period at the end of flowering – complete pouring of seeds, foliar feeding against the background of seed inoculation with various drugs contributed to the extension of this period by 1-3 days compared to the control (without feeding) and by 4-6 days compared to the absolute control of the experiment.

Conclusions. On the basis of phenological observations of the growth processes and development of soybean plants, it was established that both the duration of the periods between individual phases of growth and development, and the duration of the growing season as a whole, were significantly influenced by both the hydrothermal conditions of the year and the organized factors that were set for study, namely seed inoculation and foliar fertilization. The most favorable conditions for the growth, development and optimal passage of interphase periods by soybean plants were formed when growing them on experimental variants, where seed inoculation

was carried out with the preparation Bio-inoculant BTU (2 l/t) in combination with foliar fertilizing with organo-mineral fertilizer Helprost soy (2.5 l/ha).

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АНОТАЦІЯ

ВПЛИВ ГІДРОТЕРМІЧНИХ УМОВ, ОБРОБКИ НАСІННЯ ТА ПОЗАКОРЕНЕВИХ ПІДЖИВЛЕНЬ НА ПРОХОДЖЕННЯ ФАЗ РОСТУ І РОЗВИТКУ РОСЛИН СОЇ

У статті наведено дослідження з розробки технологічних прийомів вирощування сої залежно від гідротермічних умов, обробки насіння та позакореневих підживлень на проходження фаз росту і розвитку рослин. Актуальність роботи підсилюється завданнями прикладного дослідження, що виконується за рахунок коштів державного бюджету на тему: «Розробка екологоорієнтованих технологій вирощування біоенергетичних культур для забезпечення енергонезалежності та ґрунтозбереження задля формування кліматичної нейтральності». Мета роботи обумовлена необхідністю розробки й обґрунтування біологізованих елементів технологій вирощування сої. Сюди належить формування та забезпечення їхнього сталого виробництва з урахуванням біологічних вимог рослин до гідротермічних умов регіону. Також існує потреба у модернізації окремих технологічних прийомів й оптимізації їхньої комплексної дії у технологічному циклі вирощування сої. Матеріалом досліджень були сорти сої вітчизняної селекції – Медісон і Діадема Поділля. На основі проведених фенологічних спостережень за ростовими процесами й розвитком рослин сої можна зробити висновок, що як на тривалість періодів між окремими фазами росту й розвитку, так і на тривалість вегетаційного періоду загалом суттєвий вплив мали як гідротермічні умови року, так і організовані чинники, що були поставлені на вивчення, зокрема інокуляція насіння та позакореневі підживлення. Визначено, що для оптимальних параметрів набубнявіння та проростання насіння сої потребує 140–160 % води від своєї маси. Проростки сої через нестачу вологи сильно пригнічуються. Відтак

перший критичний період вологозабезпечення у сої настає у фазі гілкування, а другий – більш інтенсивний – у фазі формування та наливання насіння. Визначено найбільш сприятливі умови для росту, розвитку й оптимального проходження міжфазних періодів рослинами сої, що формувались за вирощування їх на варіантах досліду, де проводили інокуляцію насіння препаратом Біо-інокулянт БТУ (2 л/т) у поєднанні з позакореневими підживленнями органо-мінеральним добривом Хелпрост соя (2,5 л/га).

Ключові слова: *соя, сорт, передпосівна обробка насіння, позакореневі підживлення, критичні періоди, міжфазні періоди.*

Табл. 2. Літ. 13.

Інформація про авторів

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