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**PHYTOPATHOLOGICAL  
MONITORING AND  
PROTECTION OF SOYBEANS  
FROM MAJOR DISEASES**

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This article presents the results of a study on the effect of fungicide application on the development of the major soybean pathogens during the early stages of crop development and throughout the growing season, as well as on the indicators used to evaluate the efficiency of soybean production. As a result of the phytopathological monitoring conducted in the soybean agroecosystem, the species composition of soybean pathogens was determined. The phytopathogenic complex was dominated by *Alternaria* blight and *Septoria* leaf spot, accounting for 27,8% and 21,5% of the total disease incidence, respectively. A somewhat lower prevalence was recorded for *Fusarium* root rot (16,3%) and downy mildew (14,6%). *Ascochyta* blight (10,4%), *Cercospora* leaf spot (3,2%), white mold (2,6%), and gray mold (2,0%) occurred considerably less frequently in soybean crops. Bacterial diseases accounted for 1.4% of the total disease complex, whereas viral infections represented only 0,2%.

It was established that the highest level of biological efficacy in the soybean protection system was achieved through the integrated application of pre-sowing seed treatment with fungicidal seed dressers followed by the application of the fungicide Abacus during the crop growing season. The maximum efficacy against *Fusarium* root rot (97%) was achieved by combining the fungicidal seed treatment Vibrance at a rate of 1,0 l/t with the fungicide Abacus at a rate of 2,0 l/ha. At the same time, the highest technical efficacy in controlling *Alternaria* blight and *Septoria* leaf spot (97–98%) was recorded when the seed dresser Standak Top was applied at a rate of 2,0 l/t in combination with the fungicide Abacus at a rate of 2,0 l/ha.

The analysis of yield performance demonstrated that the application of the evaluated fungicide systems significantly increased soybean productivity compared with the untreated control. Seed yield in the experimental treatments ranged from 2,72 to 3,02 t/ha, whereas in the control it did not exceed 2,37 t/ha. The highest seed yield (3,02 t/ha) was obtained following the integrated application of the fungicidal seed treatment Standak Top at a rate of 2,0 l/t before sowing, followed by the foliar application of the fungicide Abacus at 2,0 l/ha during the growing season. Under this treatment, the yield increase reached 0,65 t/ha, or 27,4% compared with the control. The obtained results indicate that the combination of pre-sowing seed treatment and fungicide application during the growing season effectively suppresses the development of the disease complex, improves the phytosanitary status of soybean crops, and creates favorable conditions for a more complete realization of the crop's yield potential within modern soybean production technology.

**Keywords:** soybean, pathogens of diseases, fungicides, pre-sowing seed treatment efficiency, yield.

**Table 4, Fig 1, Ref. 18.**

**Introduction.** Under the context of the ongoing transformation of global agricultural production, soybean (*Glycine max* (L.) Merrill.) has emerged as one of the world's most strategically important agricultural crops, ranking fourth in global production after maize, wheat, and rice.



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Its significance is determined by its broad applicability in the food, feed, and processing industries, the exceptional nutritional value of its seeds, and its capacity to enhance soil fertility through the symbiotic fixation of atmospheric nitrogen by *Rhizobium* bacteria.

Under the ongoing transformation of global agricultural production systems, soybean has become one of the world's most strategically important agricultural crops, ranking fourth in global production after maize, wheat, and rice. Its strategic significance is обусловлена its extensive utilization in the food, feed, and processing industries, the high nutritional and biological value of its seeds, and its distinctive agronomic function in enhancing soil fertility through the biological fixation of atmospheric nitrogen in symbiosis with *Rhizobium* spp. Furthermore, soybean contributes to the sustainability of agroecosystems by reducing the dependence on synthetic nitrogen fertilizers, improving soil fertility, and serving as a valuable predecessor in crop rotations [2, 4, 9].

Compared with many cereal crops, soybean grain typically requires minimal or no additional drying after harvest, which contributes to reduced energy consumption, lower production costs, and improved resource efficiency within production systems. Currently, soybean occupies a leading position among global protein-producing crops, accounting for more than 25% of the world's plant-based protein supply utilized in food production and animal feed industries [1]. The combination of high nutritional value, technological versatility, and multifunctional utilization has established soybean as an essential component of modern agricultural production systems and a key element of global food security. Therefore, soybean remains one of the most economically valuable and strategically important agricultural crops, contributing significantly to food security, sustainable livestock production, and the advancement of environmentally balanced agricultural systems.

**Analysis of recent research and publications.** In recent years, soybean agroecosystems have exhibited a steady increase in the prevalence and harmfulness of phytopathogenic micromycetes, driven by the combined effects of biotic, abiotic, and anthropogenic factors. The principal factors contributing to the accumulation and dissemination of infectious agents include the use of infected seed material, violation of scientifically based crop rotation systems, non-compliance with optimal sowing dates, and deviations from the recommended soybean cultivation practices [8].

Seed-borne infection poses a particular threat, as infected seeds serve not only as a primary source of inoculum but also as a factor that significantly reduces seed quality. Infection of soybean seeds by phytopathogenic micromycetes leads to decreased germination energy, laboratory and field germination, seed viability, and ultimately impairs the establishment of a uniform and vigorous crop stand. The use of infected seed material promotes the persistence and dissemination of pathogens throughout the entire soybean production cycle, including the growing season, harvesting, transportation, and storage of the harvested crop.

Disease development in soybean stands results in a reduction in plant population density, inhibits plant growth and development, decreases the assimilative leaf area, and disrupts key physiological and biochemical processes. The combined effects of these pathological changes lead to a substantial decline in the productivity of soybean agroecosystems, accompanied by reductions in both seed yield and quality, thereby significantly decreasing the economic value of the harvested crop [10, 11].

The soybean pathogenic complex comprises fungal, bacterial, and viral pathogens whose occurrence, development, and harmfulness are governed by the interaction of abiotic environmental conditions, the biological characteristics of the pathogens, and the genetically determined resistance of soybean cultivars. Pathogens are capable of infecting soybean plants throughout all stages of ontogenesis, leading to reductions in plant stand density, disruption of normal growth and development, and significant losses in crop productivity. Under environmental conditions conducive to disease development, seed yield losses may reach up to 30%, accompanied by decreases in seed protein and oil contents of 4–5% and 3–7%, respectively [15].

According to scientific studies, soybean crops in Europe are affected by 44 fungal, 13 bacterial, and 4 viral diseases [13]. This diversity of pathogens reflects the high phytosanitary vulnerability of the crop and underscores the necessity of developing and implementing effective integrated crop protection strategies. At the same time, modern technologies of intensive soybean cultivation, based on the use of increased rates of mineral fertilizers, herbicides and other chemical agents, along with increasing productivity, can contribute to the formation of favorable conditions for the development and spread of phytopathogenic organisms. The result is increased damage to plants, deterioration of their physiological state and a decrease in the realization of the productive potential of the crop, which ultimately leads to significant crop losses [5, 14].

The principal fungal pathogens associated with soybean diseases include *Fusarium oxysporum* Sch., the causal agent of Fusarium wilt; *Peronospora manshurica* Sydow., responsible for downy mildew; *Septoria glycines* Hemmi., causing Septoria leaf spot; *Ascochyta sojaecola* Abr.; species of the genus *Alternaria*; *Colletotrichum truncatum* Andrus & Moore., the pathogen of anthracnose; *Cercospora sojina* Hara., the causal agent of Cercospora leaf spot; *Sclerotinia libertiana* Fuck., associated with Sclerotinia stem rot (white mold); and *Phakopsora pachyrhizi* Syd. & P. Syd., the pathogen of soybean rust [5]. These pathogens differ considerably in their biological characteristics, infection mechanisms, epidemiology, and levels of harmfulness. Nevertheless, under favorable environmental conditions, individual pathogens or their complexes may significantly impair soybean growth and development, resulting in considerable reductions in yield potential, deterioration of seed quality, and decreased technological properties of harvested products.

The bacterial disease complex of soybean is represented primarily by *Pseudomonas savastanoi* pv. *glycinea*, *Pseudomonas syringae* pv. *glycinea*, and *Xanthomonas axonopodis* pv. *glycines*.

Other bacterial diseases occur much less frequently, have a local distribution and, as a rule, do not acquire significant economic importance. Viral diseases of soybean are mainly represented by soybean mosaic virus (SMV) and alfalfa mosaic virus (AMV). Plant infection by these viruses leads to a significant decrease in yield, deterioration of sowing and technological qualities of seeds, and also creates prerequisites for the development of mixed infections, which complicates the phytosanitary condition of crops and reduces the effectiveness of protective measures [6].

Despite significant progress in the development of plant protection products, there are currently no preparations for treating seeds or vegetative plants that would provide consistently high and guaranteed effectiveness in controlling bacterial diseases of soybeans. In addition, the use of chemical protection agents is often accompanied by a number of undesirable side effects. In particular, numerous active substances used for pathogen control may exhibit non-target effects, negatively influencing not only phytopathogenic microorganisms but also beneficial soil microbiota, including symbiotic nitrogen-fixing bacteria of the genus. These microorganisms establish a highly specific mutualistic interaction with soybean roots, forming nodules that constitute the basis of an efficient biological nitrogen fixation system. The disruption of legume–rhizobium symbiosis may result in a significant reduction in nitrogen fixation activity, deterioration of plant nitrogen nutrition, and, consequently, a decrease in soybean productivity and yield stability. Therefore, the integration of microbial inoculants aimed at enhancing the establishment and functioning of effective legume–rhizobium associations is considered one of the most promising and scientifically substantiated approaches for improving soybean resistance to bacterial diseases while maintaining ecological sustainability of agricultural production systems. Such biological preparations contribute to the optimization of plant physiological processes, stimulate growth and development, enhance biological nitrogen fixation, improve adaptive responses to environmental stresses, and increase the natural resistance of soybean plants to bacterial pathogens [10].

Soybean Fusarium wilt Fusarium wilt, caused by *Fusarium oxysporum* Sch., is among the most widespread and economically significant diseases affecting soybean crops. The disease is characterized by its high harmfulness, as it infects plants at all stages of organogenesis, suppressing their growth and development, impairing their physiological condition, reducing productivity, and causing significant losses in both yield and seed quality. The disease infects pathogens affect plants at different stages of ontogenesis, causing the greatest damage during seed germination and seedling emergence. The initial symptoms include browning and rotting of seedlings. Brown, circular lesions develop on the cotyledons and gradually enlarge into ulcer-like necrotic areas. Under conditions of high humidity, the affected tissues become covered with a pale pink mycelial and conidial mass, followed by tissue maceration, which often results in plant death. In cases of mild disease development, infected plants continue their growth; however, their vegetative development is significantly suppressed, leading to reduced productivity.

Infected seeds become shriveled, exhibit reduced germination capacity, or produce weak and non-viable seedlings. The primary sources of infection include contaminated seeds, infected crop residues, and infested soil [5].

Species of the genus *Fusarium* are characterized by considerable ecological plasticity. Although many of them are saprophytic, under favorable conditions they are capable of switching to a parasitic lifestyle. Continuous soybean cultivation in monoculture or highly saturated crop rotations promotes the accumulation of inoculum and the selection of specialized, more virulent pathogen strains, resulting in shifts in the population structure of *Fusarium* spp. and an increased risk of disease outbreaks. The severity of soybean Fusarium wilt can be reduced through the implementation of an integrated disease management strategy [16].

Downy mildew, caused by *Peronospora manshurica* Sydow, is among the most widespread and economically significant diseases affecting soybean worldwide. The pathogen is an obligate biotroph whose development and reproduction are possible exclusively within the living tissues of the host plant, as it acquires the nutrients required for growth solely from metabolically active host cells. Secondary infection occurs through the production of conidia, which are disseminated primarily by wind currents and rain splash. Young soybean leaves are particularly susceptible to infection, whereas mature leaves generally exhibit increased resistance to pathogen penetration and colonization. The pathogenic effect of downy mildew on soybean plants is associated with profound disturbances in physiological and biochemical processes, primarily manifested by inhibition of vegetative development and reduction of the functional photosynthetic apparatus. The decrease in photosynthetically active leaf area results in impaired carbon assimilation, disruption of assimilate accumulation, and deterioration of reproductive processes, which ultimately leads to substantial yield losses. Under favorable abiotic conditions for pathogen infection and disease progression, yield reductions may reach 40%, with a decrease in 1,000-seed weight exceeding 6%. Severe infection of soybean pods can cause a reduction in pod mass of up to 45% and seed weight losses of approximately 50% [5].

Soybean ascochyta blight, caused by *Ascochyta sojaecola* Abr., represents a significant phytopathological constraint in soybean production systems due to its wide distribution and potential impact on crop productivity. The pathogen exhibits a polycyclic development pattern, with infection occurring through both seed-borne inoculum and secondary inoculum generated during the vegetation period. Pycnidiospores formed in pycnidia on infected plant residues and tissues play a crucial role in disease propagation, being actively disseminated by precipitation and air currents. The epidemiological development of the disease is strongly influenced by environmental conditions, particularly temperature and moisture, with maximum pycnidiospore germination observed at temperatures of 20–25 °C. The pathogen survives primarily in infected plant residues and seeds as dormant mycelium and pycnidia containing pycnidiospores. These survival structures ensure the long-term persistence of the pathogen in agroecosystems and serve as the primary source of inoculum for infection during subsequent growing seasons.

The development of Ascochyta blight causes significant phytopathological damage, including reductions in laboratory and field seed germination rates of up to 40%, decreased plant stand density, suppression of vegetative growth and physiological development, and, consequently, a decline in overall crop productivity. Under favorable environmental conditions promoting intensive disease progression, yield losses in soybean crops may reach 20%.

It is often considered one of the most common and economically significant diseases of soybean. Soybean Septoria leaf spot, caused by *Septoria glycines* Hemmi, develops most intensively from the flowering stage to the beginning of pod formation. The pathogen is characterized by a broad ecological plasticity, remaining viable within a temperature range of +5 to +36 °C, while optimal conditions for its growth and sporulation occur at +22 to +28 °C in combination with relative air humidity above 80%. The main sources of primary inoculum are infected soybean seeds and crop residues, where the pathogen persists in the form of pycnidia containing pycnidiospores. During the vegetation period, pycnidiospores are disseminated mainly by rain splash and wind currents, resulting in the infection of soybean leaf tissues. Subsequent development of secondary infection cycles promotes gradual pathogen accumulation and contributes to the progressive spread and intensification of the disease within soybean agrocenoses [7, 17].

The epiphytotic development of soybean Septoria leaf spot is strongly associated with elevated average daily air temperatures accompanied by abundant precipitation during the second half of July and August. Under such environmental conditions, the disease may progress rapidly, causing premature defoliation of up to 50% of the leaf area and resulting in yield losses ranging from 15% to 30% [12].

Anthrachnose of soybean is caused by the phytopathogenic fungus *Colletotrichum truncatum* Andrus et Moore., which is disseminated predominantly by conidia during the vegetation period. The pathogen exhibits intensive development under conditions of relative air humidity of approximately 60% and temperature ranges of +15 to +19 °C, which promotes successful host infection and the formation of secondary sources of inoculum. Symptoms of the disease are manifested as small necrotic lesions with distinct brown margins on soybean pods. Under conditions of elevated moisture, these lesions become covered with abundant conidial sporulation of the pathogen, contributing to further disease spread within agrocenoses.

The primary inoculum of the anthracnose pathogen is represented by infected plant residues and seeds, where the pathogen survives as dormant mycelium, ensuring its persistence and initiating infection processes in the following vegetation period. The disease exerts a pronounced negative effect on crop productivity by reducing plant emergence and stand density, impairing seed quality and sowing properties, limiting vegetative development, and decreasing the photosynthetic potential of plants due to the reduction of the assimilative leaf area. As a consequence, anthracnose causes considerable yield losses and adversely affects the economic efficiency of soybean cultivation [5].

In recent years, *Alternaria* blight caused by phytopathogenic fungi belonging to the genus *Alternaria* spp. has become an increasingly significant phytopathological constraint in soybean production systems. The disease is characterized by the development of necrotic lesions on leaf tissues, resulting in a progressive decline in the photosynthetically active surface of plants, premature senescence, and accelerated defoliation. The disruption of assimilative processes caused by pathogen colonization leads to reduced accumulation of photosynthetic products, impaired reproductive development, and decreased seed productivity. The severity of yield losses caused by *Alternaria* blight is determined by a complex interaction between environmental conditions, pathogen aggressiveness, soybean growth stage, and cultivar resistance. Under favorable conditions for disease development, yield reductions may reach 20% or more, which highlights the importance of effective monitoring and integrated disease management strategies in soybean agrocenoses [18].

To minimize the adverse impact of fungal diseases on soybean crops, the application of modern chemical plant protection products is of paramount importance, with fungicides playing a leading role. Modern fungicides are characterized by high biological efficacy and selective activity, and their mode of action is based on disrupting essential biochemical processes in the cells of phytopathogenic fungi, thereby inhibiting their growth, development, and sporulation. In addition to their direct fungitoxic activity, certain active ingredients exhibit physiological (plant health-promoting) effects by activating the plant's defense mechanisms, inducing systemic resistance, and enhancing the adaptive capacity of plants to biotic stress factors.

A major challenge associated with the intensive use of fungicides is the development of resistance in populations of phytopathogenic fungi to the active ingredients of fungicidal products. According to the studies of M. G. Roth et al. [3], the prolonged, systematic, and indiscriminate application of fungicides exerts strong selection pressure on pathogen populations, promoting the selection and spread of resistant strains. As a result, the sensitivity of pathogens to fungicides gradually declines, leading to a significant reduction in the biological efficacy of fungicides, complicating disease management, and necessitating the implementation of anti-resistance strategies within integrated plant protection systems.

Despite the widespread use of fungicides for soybean disease management worldwide, the determination of optimal application timing remains insufficiently studied. In most major soybean-producing countries, fungicides are applied prophylactically according to crop phenology, with the predominant recommendation being applications during the reproductive growth stages from R3 (beginning pod) to R5 (beginning seed). This growth stage-based strategy has gained broad acceptance because of its practical simplicity and ease of implementation. Unlike disease forecasting or threshold-based approaches, it does not require prior detection of disease symptoms, assessment of disease severity, or phytopathological diagnosis, making it particularly suitable for large-scale commercial soybean production systems [17].

Studies conducted in Iowa (USA) demonstrated that the application of fungicides based on the active ingredients tebuconazole and pyraclostrobin, either individually or in combination, at the soybean growth stages R1, R3, and R5 did not result in a statistically significant increase in grain yield. Under conditions where fungal diseases were absent, the use of these fungicides also failed to produce any non-fungicidal physiological effect capable of positively influencing crop productivity.

Similar findings were reported by M. L. Ellis et al. [16], who demonstrated that the absence of fungicide protection in soybean production resulted in a grain yield reduction of 0,22–0,80 t/ha. In contrast, fungicide application increased soybean yield by an average of 0,46 t/ha, confirming the high effectiveness of fungicide protection as an essential component of soybean production technology.

In the soybean protection system against seed-borne pathogens, pre-sowing seed treatment plays a crucial role. The application of fungicidal seed dressings ensures effective elimination of seed-borne infections and protects seedlings during the early stages of organogenesis from infection by soil-borne phytopathogens. Particular attention should be paid to the use of fungicides compatible with *Bradyrhizobium* spp., as they have minimal adverse effects on the establishment of the nitrogen-fixing symbiosis. Such active ingredients include prothioconazole (300 g/l) at the recommended application rate of 0,2–0,4 l/t of seed, fludioxonil (25 g/l) in combination with metalaxyl-M (10 g/l) at 1.0 l/t, and the combination of carboxin (200 g/l) and thiram (200 g/l) at an application rate of 2,0 l/t of seed. Other modern fungicidal formulations characterized by high biological efficacy and compatibility with microbial inoculants are also widely used. The integrated and scientifically substantiated combination of pre-sowing fungicidal seed treatment with inoculant application promotes the development of a highly efficient legume–rhizobium symbiosis, improves the phytosanitary status of the agroecosystem, enhances the efficiency of biological nitrogen fixation, preserves soil fertility, and ensures the production of high soybean yields with superior quality characteristics.

Pre-sowing soybean seed treatment with a fungicide containing carboxin 200 g/l and thiram 200 g/l, combined with the application of a fungicide based on pyraclostrobin 62,5 g/l and epoxiconazole 62,5 g/l during the growing season, resulted in an increase in soybean seed yield from 2,04 t/ha in the untreated control (no seed treatment, two-field crop rotation) to 2,65 t/ha under three- and four-field crop rotations [9, 18].

**Materials and methods of research.** The research was conducted in accordance with generally accepted methods used in phytopathological studies [5].

The soybean cultivar ES Mentor developed by Lidea was used in the experiments. Field trials were established on experimental plots with an area of 50 m<sup>2</sup>, arranged systematically in three replications. This experimental design ensured the statistical reliability of the obtained results.

**Assessments and Observations.** Phytosanitary monitoring of the soybean agroecosystem was conducted to identify the major pathogens affecting the crop. Visual inspections were performed in each experimental plot using four replications.

At each assessment point, 20 soybean plants were examined for the presence of disease symptoms, and the incidence and severity of diseases were evaluated. Phytopathological assessments of disease development in the soybean agroecosystem were conducted at the phenological stages of the first pair of true leaves (BBCH 10–12) and full flowering (BBCH 64–66). During the assessments, disease incidence (percentage of infected plants) and disease severity were determined according to generally accepted phytopathological methods.

The resistance of soybean plants to the major diseases was evaluated according to the percentage of the affected plant surface, following the current methodological guidelines and generally accepted phytopathological assessment methods.

Under field conditions, the efficacy of chemical fungicides representing different classes of chemical compounds and possessing different modes of action against the most prevalent soybean pathogens was evaluated. The effects of fungicide application on disease development, soybean productivity, and seed quality were assessed. The experiment included the following treatment variants (table 1.):

Yield structure was determined by analyzing plant samples collected at the full seed maturity stage from a sampling area of 0,25 m<sup>2</sup> in three replications. The following yield components were evaluated: plant density (plants m<sup>-2</sup>), number of pods per plant, number of seeds per pod, number and weight of seeds per plant, and thousand-seed weight (TSW) [5].

Table 1

**Variants of the experiment to assess the effectiveness of fungicides for spraying soybean crops against the main pathogens**

| Variant | Product/Trade name, Active ingredient (%)                                                 |                                                                                                                                                           |
|---------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
|         | Seed treatment before sowing                                                              | Application of fungicides in the BBCH 61 phase (beginning of flowering)                                                                                   |
| 1.      | Control (without fungicide application)                                                   | -                                                                                                                                                         |
| 2.      | -                                                                                         | Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) 1,0 l/t                                                                                           |
| 3.      | Maxim Advance (fludioxonil 25 g/l, metalaxyl-M 20 g/l, thiabendazole, 150 g/l) 1,25 l/t   | Maxim Advance (fludioxonil 25 g/l, metalaxyl-M 20 g/l, thiabendazole, 150 g/l) 1,25 l/t + Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) 1,0 l/t |
| 4.      | Vibrance (fludioxonil 25 g/l, metalaxyl-M 37,5 g/l, sedaxan 50 g/l) 1,0 l/t               | Vibrance (fludioxonil 25 g/l, metalaxyl-M 37,5 g/l, sedaxan 50 g/l) 1,0 л/т + Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) 1,0 l/t             |
| 5.      | Standak Top (fipronil 250 g/l, pyraclostrobin 25 g/l, thiophanate-methyl 225 g/l) 2,0 l/t | Standak Top (fipronil 250 g/l, pyraclostrobin 25 g/l, thiophanate-methyl 225 g/l) 2 л/т + Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) 1,0 l/t |

Source: compiled by the authors

Based on the results of the assessments, the incidence and severity of each investigated disease were determined for every experimental treatment. Disease incidence (P, %) was calculated using the following formula 1.1.:

$$P = n/N \times 100, (1.1)$$

де P – disease incidence, %;

n – number of infected plants (or assessed units);

N – total number of examined plants (or assessed units).

Disease development (R) of soybeans was calculated using the generally accepted formula 1.2.:

$$R = \Sigma(A \times B) / K \times N \times 100, (1.2)$$

where A is the number of plants with the same symptoms;

B is the score corresponding to these symptoms;

$\Sigma(A \times B)$  is the sum of the products of indicators A and B;

K is the total number of plants examined;

N is the highest score of plant damage on the assessment scale

The effectiveness of the drugs was determined by formula 1.3:

$$Ed = 100 (P_c - P_d) / P_c (1.3)$$

Ed – drug efficacy %;

P<sub>c</sub> – disease development indicator in the control;

P<sub>d</sub> – disease development indicator in the experimental variant

100 – conversion factor, %.

Grain yield was determined on a plot basis by harvesting plants at full seed maturity using a plot combine harvester. Following threshing, the grain mass was recorded and adjusted to a standard seed moisture content of 12% and 100% seed purity. Grain yield was subsequently calculated and expressed in t ha<sup>-1</sup>. Experimental data were subjected to analysis of variance (ANOVA) using Statistica 12.0 software.

**Research results.** It was established through phytosanitary monitoring of soybean crops that the phytopathogenic complex comprised diseases of fungal, bacterial, and viral etiology. Among the fungal diseases identified were *Alternaria* leaf spot, *Septoria* leaf spot, *Fusarium* root rot, downy mildew, *Ascochyta* blight, white mold, and gray mold. Bacterial diseases were represented by bacterial blight, while viral infections occurred only sporadically, with isolated infected plants recorded during the monitoring period.

Analysis of the disease distribution structure within the soybean phytopathogenic complex demonstrated that *Alternaria* leaf spot and *Septoria* leaf spot were the dominant diseases, accounting for 27,8% and 21,5% of the total disease incidence, respectively (Fig. 1). A comparatively lower proportion was represented by *Fusarium* root rot (16,3%) and downy mildew (14,6%). The occurrence of *Ascochyta* blight was estimated at 10,4%, whereas *Cercospora* leaf blight, white mold, and gray mold were detected less frequently, comprising 3,2%, 2,6%, and 2,0% of the phytopathogenic complex, respectively. Bacterial diseases constituted only 1,4% of the total disease spectrum, while viral infections were of negligible importance, accounting for merely 0,2%.

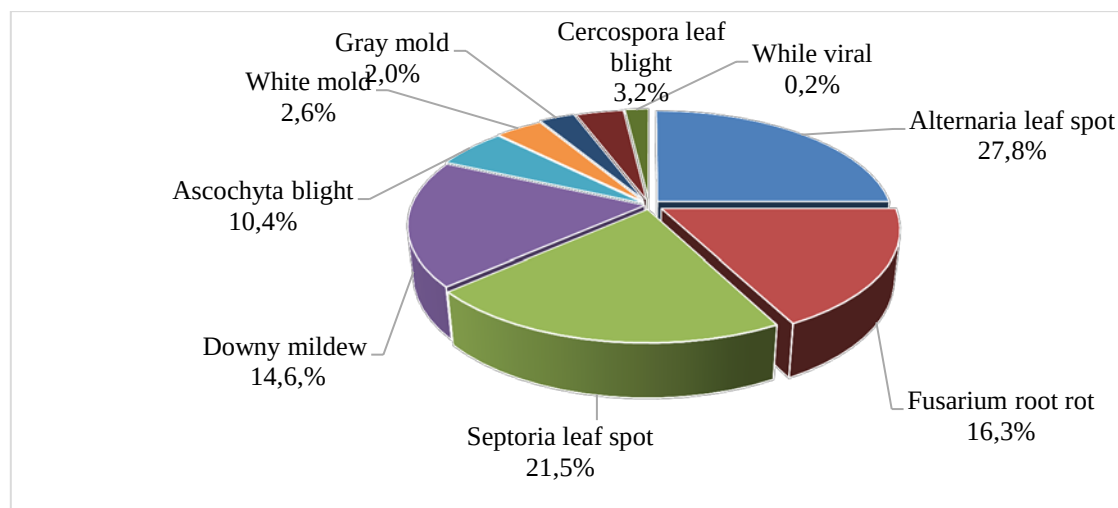


**Fig. 1. Shares of major diseases in the soybean agroecosystem during the growing season (2025), %**

*source: formed on the basis of own research*

The obtained results demonstrated that the phytopathogenic complex of soybean in the studied agroecosystems was dominated by fungal diseases, with *Alternaria* leaf spot, *Septoria* leaf spot, *Fusarium* root rot, and downy mildew representing the most phytosanitarily significant pathogens. These diseases largely determined the overall phytopathological status of soybean crops and, therefore, should be regarded as the primary targets in the development of an effective fungicide-based disease management strategy.

The results of the study showed that at the first trifoliate leaf stage (BBCH 12), the predominant soybean diseases were *Fusarium* root rot, *Alternaria* blight, and *Septoria* leaf spot. Phytopathological assessments in the untreated control plots revealed disease severities of 8,2% for *Fusarium* root rot, 11,6% for *Alternaria* blight, and 7,4% for *Septoria* leaf spot. These results indicate that *Alternaria* blight was the dominant disease during the early stage of soybean development, exhibiting the highest severity among the diseases recorded (Table 2).

Seed treatment with the fungicidal dressing Vibrance at a rate of 1,0 l/t provided high technical efficacy against the major soybean diseases, reaching 88% against *Alternaria* blight, 86% against *Fusarium* disease, and 85% against *Septoria* leaf spot. Similarly, seed treatment with Standak Top at 2,0 l/t demonstrated technical efficacy of 85%, 90%, and 88% against *Alternaria* blight, *Fusarium* disease, and *Septoria* leaf spot, respectively. These results indicate that both fungicidal seed dressings effectively suppressed early-season disease development, with Standak Top exhibiting superior efficacy against *Fusarium* disease and *Septoria* leaf spot, while Vibrance showed slightly greater effectiveness against *Alternaria* blight.

The obtained results demonstrated that the highest technical efficacy against *Alternaria* blight was achieved following seed treatment with Maxim Advance at a rate of 1,25 l/t and Standak Top at 2,0 l/t.

Table 2

**Intensity of development of main diseases in soybean crops in the phase of the first trifoliolate leaf (BBCH 12) depending on seed treatment with fungicides (average for 2024–2025), %**

| Variant | Product/Trade name,<br>Active ingredient (%)                                               | Consumpti<br>on norms<br>of the drug<br>kg, l/ha | Fusarium<br>disease |                    | Alternaria<br>blight |                    | Septoria leaf<br>spot |                    |
|---------|--------------------------------------------------------------------------------------------|--------------------------------------------------|---------------------|--------------------|----------------------|--------------------|-----------------------|--------------------|
|         |                                                                                            |                                                  | R, %                | E <sub>t</sub> , % | R, %                 | E <sub>t</sub> , % | R, %                  | E <sub>t</sub> , % |
| 1       | Control                                                                                    | -                                                | 8,2                 | -                  | 11,6                 | -                  | 7,4                   | -                  |
| 2       | Maxim Advance<br>(fludioxonil 25 g/l,<br>metalaxyl-M 20 g/l,<br>thiabendazole, 150 g/l)    | 1,25                                             | 1,4                 | 83                 | 1,4                  | 88                 | 1,3                   | 82                 |
| 3       | Vibrance (fludioxonil 25<br>g/l, metalaxyl-M 37,5 g/l,<br>sedaxan 50 g/l)                  | 1,0                                              | 1,0                 | 88                 | 1,6                  | 86                 | 1,1                   | 85                 |
| 4       | Standak Top (fipronil 250<br>g/l, pyraclostrobin 25 g/l,<br>thiophanate-methyl 225<br>g/l) | 2,0                                              | 1,2                 | 85                 | 1,2                  | 90                 | 0,9                   | 88                 |

Note: R – disease development, %; E<sub>t</sub> – technical efficiency, %  
source: formed on the basis of own research

The greatest efficacy in suppressing Fusarium root rot was recorded for Vibrance applied at 1,0 l/t, whereas the highest level of protection against Septoria leaf spot was provided by Standak Top at an application rate of 2,0 l/t. These findings indicate that the effectiveness of seed treatment products varied depending on the target pathogen, highlighting the importance of selecting seed dressers according to the predominant disease complex. According to the phytopathological assessments conducted in soybean crops at the flowering stage (BBCH 65), disease severity in the untreated control reached 11,2% for Fusarium root rot, 15,9% for Alternaria blight, and 14,6% for Septoria leaf spot. These findings indicate a marked increase in disease development compared with the earlier growth stage, highlighting the susceptibility of soybean plants to pathogen infection during the flowering period (Table 3).

The application of the fungicide Propuls at a rate of 1,0 l/ha during the soybean growing season significantly suppressed the development of the investigated diseases. Under this treatment, disease severity was reduced to 2,4% for Fusarium root rot, 2,3% for Alternaria blight, and 2,4% for Septoria leaf spot, indicating a high level of fungicidal efficacy in limiting the progression of the major soybean diseases during the early stages of plant development. The highest level of disease suppression was achieved through the integrated fungicide application strategy, comprising pre-sowing seed treatment followed by foliar application of Propuls at a rate of 1,0 l/ha during the growing season. This treatment provided the most effective protection against the major soybean diseases, reducing the severity of Fusarium root rot to 0,3–0,4%, Alternaria blight to 0,3–0,8%, and Septoria leaf spot to 0,5–1,1%.

Table 3

**Intensity of development and effectiveness of fungicidal protection against major diseases of soybean crops in the flowering phase (BBCH 65) (average for 2024–2025), %**

| Variant                                                                                                                                                        | Fusarium disease |                    | Alternaria blight |                    | Septoria leaf spot |                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------------|-------------------|--------------------|--------------------|--------------------|
|                                                                                                                                                                | R, %             | E <sub>t</sub> , % | R, %              | E <sub>t</sub> , % | R, %               | E <sub>t</sub> , % |
| Control                                                                                                                                                        | 11,2             | -                  | 15,9              | -                  | 14,6               | -                  |
| Maxim Advance (fludioxonil 25 g/l, metalaxyl-M 20 g/l, thiabendazole, 150 g/l) 1,25 l/t                                                                        | 3,4              | 70                 | 3,5               | 78                 | 3,9                | 73                 |
| Vibrance (fludioxonil 25 g/l, metalaxyl-M 37,5 g/l, sedaxan 50 g/l) (1,0 l/t)                                                                                  | 2,9              | 74                 | 3,9               | 75                 | 3,7                | 75                 |
| Standak Top (fipronil 250 g/l, pyraclostrobin 25 g/l, thiophanate-methyl 225 g/l) (2,0 l/t)                                                                    | 3,1              | 72                 | 3,6               | 77                 | 3,3                | 77                 |
| Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) (1,0 l/t)                                                                                              | 2,4              | 79                 | 2,3               | 86                 | 2,4                | 84                 |
| Maxim Advance (fludioxonil 25 g/l, metalaxyl-M 20 g/l, thiabendazole, 150 g/l) (1,25 l/t) + Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) (1,0 l/t)  | 0,4              | 96                 | 0,6               | 96                 | 1,1                | 92                 |
| Vibrance (fludioxonil 25 g/l, metalaxyl-M 37,5 g/l, sedaxan 50 g/l) (1,0 l/t) + Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) (1,0 l/t)              | 0,3              | 97                 | 0,8               | 95                 | 0,7                | 95                 |
| Standak Top (fipronil 250 g/l, pyraclostrobin 25 g/l, thiophanate-methyl 225 g/l) (2,0 l/t)+ Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) (1,0 l/t) | 0,4              | 96                 | 0,3               | 98                 | 0,5                | 97                 |

Note: R – disease development, %; Et – technical efficiency, %

source: formed on the basis of own research

At the flowering stage, the protective effect of fungicidal seed treatments applied alone decreased progressively. Their biological efficacy against Fusarium root rot, Alternaria blight, and Septoria leaf spot ranged from 70–74%, 75–78%, and 73–77%, respectively. These findings indicate that although pre-sowing seed treatment provides substantial early-season protection, its effectiveness diminishes as the crop develops. Therefore, to maintain reliable disease suppression during the critical reproductive stages of soybean growth, seed treatment should be integrated with foliar fungicide applications during the growing season.

It was established that the application of the fungicide Propuls at a rate of 1,0 l/ha to growing soybean plants provided biological efficacy against Fusarium root rot, Alternaria blight, and Septoria leaf spot of 79%, 84%, and 86%, respectively.

However, the highest levels of disease control were achieved by combining pre-sowing seed treatment with fungicidal seed dressers followed by the application of Abacus during the crop growing season. In particular, the maximum biological efficacy against *Fusarium* root rot (97%) was obtained with the treatment scheme Vibrance (1.0 l/t) + Propuls (1,0 l/ha), whereas the highest level of protection against *Alternaria* blight and *Septoria* leaf spot (97–98%) was achieved with the combined application of Standak Top (2.0 l/t) + Propuls (1,0 l/ha). These findings indicate that integrating pre-sowing seed treatment with subsequent foliar fungicide application during the growing season is an effective strategy for maximizing the suppression of the major soybean diseases.

One of the principal components of integrated soybean disease management is the application of fungicides to suppress the development and spread of phytopathogenic organisms. Fungicidal treatments provide effective control of major soybean diseases, preserving the photosynthetically active leaf area, maintaining the physiological and biochemical functioning of plants, and thereby promoting higher crop productivity. The effectiveness of fungicide-based protection depends not only on its biological efficacy against target pathogens but also on its contribution to the overall performance and stability of the agroecosystem. By improving the phytosanitary condition of soybean crops, fungicide application minimizes disease-induced yield losses, enhances seed quality, and ensures more stable and higher yields. Consequently, fungicide use represents a key agronomic practice for increasing both the biological and economic efficiency of soybean production.

The results of the study demonstrated that fungicidal protection significantly enhanced soybean grain yield compared with the untreated control. Grain yield across the fungicide-treated variants ranged from 2,72 to 3,02 t/ha, whereas the untreated control produced only 2,37 t/ha. The highest grain yield (3,02 t/ha) was achieved following the integrated application of the fungicidal seed treatment Standak Top at a rate of 2,0 l/t prior to sowing, combined with a foliar application of the fungicide Propuls at 1,0 l/ha during the growing season. This treatment provided a yield increase of 0,65 t/ha, corresponding to a 27,4% improvement over the untreated control. These findings indicate that the combined use of seed treatment and foliar fungicide application ensured the highest level of disease control and created favorable conditions for soybean growth and productivity, resulting in a substantial increase in grain yield. (Table 4).

Depending on the fungicide treatment, the preserved grain yield exceeded that of the untreated control by 0,40–0,65 t/ha, indicating the high biological and agronomic efficacy of the evaluated fungicides. The suppression of pathogen development contributed to maintaining the productive potential of soybean plants, resulting in a significant increase in grain yield. A positive effect of fungicide protection on the formation of the main soybean yield structure components, particularly the 1000-seed weight, was established. In the untreated control, this parameter was the lowest, amounting to 185.0 g, whereas the application of fungicides increased it to 194,2–209,2 g.

The increase in 1000-seed weight indicates improved seed formation and filling processes, which resulted from the effective suppression of disease development, preservation of the assimilative leaf area, and maintenance of a high intensity of photosynthetic activity.

Table 4

**The effect of fungicide application on weight 100-seeds and soybean yield (average for 2024–2025), %**

| Variant                                                                                                                                                         | Consumption norms of the drug kg, l/t | Weight of 1000 seeds, g | Yield, t/ha | Yield increase t/ha |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|-------------------------|-------------|---------------------|
| Control                                                                                                                                                         | -                                     | 185,4                   | 2,37        | -                   |
| Maxim Advance (fludioxonil 25 g/l, metalaxyl-M 20 g/l, thiabendazole, 150 g/l) l/t                                                                              | 1,25                                  | 194,2                   | 2,72        | 0,35                |
| Vibrance (fludioxonil 25 g/l, metalaxyl-M 37,5 g/l, sedaxan 50 g/l)                                                                                             | 1,0                                   | 196,6                   | 2,77        | 0,40                |
| Standak Top (fipronil 250 g/l, pyraclostrobin 25 g/l, thiophanate-methyl 225 g/l )                                                                              | 2,0                                   | 197,4                   | 2,86        | 0,49                |
| Propuls 250 SE (fluopyram 125 g/l and prothioconazole 125 g/l)                                                                                                  | 1,0                                   | 202,5                   | 2,68        | 0,31                |
| Maxim Advance (fludioxonil 25 g/l, metalaxyl-M 20 g/l, thiabendazole, 150 g/l) + Propuls (fluopyram 125 g/l and prothioconazole 125 g/l)                        | 1,25+1,0                              | 205,2                   | 2,89        | 0,52                |
| Vibrance (fludioxonil 25 g/l, metalaxyl-M 37,5 g/l, sedaxan 50 g/l) (1,0 l/t) + Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) (1,0 l/t)               | 1,0+1,0                               | 207,6                   | 2,92        | 0,55                |
| Standak Top (fipronil 250 g/l, pyraclostrobin 25 g/l, thiophanate-methyl 225 g/l ) (2,0 l/t)+ Propuls (fluopyram 125 g/l and prothioconazole 125 g/l) (1,0 l/t) | 2,0+1,0                               | 209,2                   | 3,02        | 0,65                |
| LSD <sub>0,5</sub>                                                                                                                                              |                                       |                         |             | 0,18                |

source: formed on the basis of own research

Collectively, these factors contributed to a more complete realization of the productive potential of soybean plants and, consequently, to the formation of higher seed yield.

**Conclusions.** The results of the phytosanitary monitoring of the soybean agrocenosis showed that *Alternaria* blight and *Septoria* leaf spot predominated in the disease structure, accounting for 27,8% and 21,5% of the total phytopathogenic complex, respectively. A somewhat lower incidence was recorded for *Fusarium* root rot (16,3%) and downy mildew (14,6%). *Ascochyta* blight (10,4%), *Cercospora* leaf spot (3,2%), white mold (2,6%), and gray mold (2,0%) occurred considerably less frequently in soybean crops. Bacterial diseases accounted for 1,4% of the total disease complex, whereas viral infections represented only 0,2%, indicating their negligible contribution to the phytopathogenic complex of soybean under the conditions of the present study.

It was established that the predominant diseases during the early stages of soybean development were Fusarium root rot, Alternaria blight, and Ascochyta blight. Seed treatment with fungicidal seed dressers provided a high level of disease control. The highest technical efficacy against Alternaria blight was achieved with Maxim Advance at 1,25 l/t and Standak Top at 2,0 l/t. The greatest efficacy against Fusarium root rot was recorded following treatment with Vibrance at 1,0 l/t, whereas the highest protective effect against Ascochyta blight was provided by Standak Top applied at a rate of 2,0 l/t.

It was established that the highest level of biological efficacy in the soybean protection system was achieved through the integrated application of pre-sowing seed treatment with fungicidal seed dressers followed by the application of the fungicide Propuls during the crop growing season. The maximum efficacy against Fusarium root rot (97%) was achieved by combining the fungicidal seed treatment Vibrance at a rate of 1,0 l/t with the fungicide Propuls at a rate of 1,0 l/ha. At the same time, the highest technical efficacy in controlling Alternaria blight and Septoria leaf spot (97–98%) was recorded when the seed dresser Standak Top was applied at a rate of 2,0 l/t in combination with the fungicide Propuls at a rate of 1,0 l/ha.

The analysis of yield performance demonstrated that the application of the evaluated fungicide systems significantly increased soybean productivity compared with the untreated control. Seed yield in the experimental treatments ranged from 2,72 to 3,02 t/ha, whereas in the control it did not exceed 2,37 t/ha. The highest seed yield (3,02 t/ha) was obtained following the integrated application of the fungicidal seed treatment Standak Top at a rate of 2,0 l/t before sowing, followed by the foliar application of the fungicide a Propuls t 1,0 l/ha during the growing season. Under this treatment, the yield increase reached 0,65 t/ha, or 27,4% compared with the control.

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### **АНОТАЦІЯ**

### **ФІТОПАТОЛОГІЧНИЙ МОНІТОРИНГ І ЗАХИСТ СОЇ ВІД ОСНОВНИХ ХВОРОБ**

У статті наведено результати досліджень щодо оцінки впливу застосування фунгіцидів на розвиток основних збудників хвороб у посівах сої на ранніх етапах органогенезу та протягом вегетаційного періоду, а також на показники продуктивності й ефективності вирощування культури.

В результаті фітопатологічного моніторингу в агроценозі сої в ході досліджень встановлено видовий склад збудників хвороб сої. Домінуюче положення у фітопатогенному комплексі займали альтернаріоз і септоріоз, частка яких становила відповідно 27,8 та 21,5 %. Деяко нижчий рівень поширення відзначено для фузаріозу (16,3 %) та пероноспорозу (14,6 %). Значно рідше у посівах сої траплялися аскохітоз (10,4 %), церкоспороз (3,2 %) біла гниль (2,6 %) та сіра гниль (2,0 %). Частка бактеріальних хвороб у загальній структурі виявлених захворювань становила 1,4 %, тоді як вірусні інфекції були представлені лише 0,2 %.

Встановлено, що найвищий рівень біологічної ефективності системи захисту посівів сої досягався за комплексного застосування передпосівної обробки насіння фунгіцидними протруйниками з подальшим внесенням фунгіциду Пропульс у період вегетації культури. Максимальну ефективність проти фузаріозу (97 %) забезпечувало поєднання фунгіцидного протруйника Вайбранс у нормі 1,0 л/т із фунгіцидом Пропульс у нормі 1,0 л/га. Водночас найвищу технічну ефективність у контролі альтернаріозу та септоріозу (97–98 %) забезпечувало застосування протруйника Стандак Топ у нормі 2,0 л/т у комплексі з фунгіцидом Пропульс у нормі 1,0 л/га.

Аналіз показників урожайності засвідчив, що застосування досліджуваних фунгіцидних систем сприяло істотному підвищенню продуктивності посівів сої порівняно з контрольним варіантом. Урожайність насіння у варіантах дослідів становила 2,72–3,02 т/га, тоді як у контролі вона не перевищувала 2,37 т/га. Найвищу врожайність – 3,02 т/га – отримано за комплексного застосування фунгіцидного протруйника Стандак Топ (2,0 л/т) для передпосівної обробки насіння з подальшим внесенням фунгіциду Пропульс (1,0 л/га) у період вегетації культури. За цього варіанта приріст урожайності досягав 0,65 т/га, або 27,4 % порівняно з контролем. Отримані результати свідчать, що поєднання передпосівної обробки насіння із застосуванням фунгіцидного захисту впродовж вегетації забезпечує ефективне стримування розвитку комплексу хвороб, сприяє поліпшенню фітосанітарного стану посівів, створює передумови для повнішої реалізації продуктивного потенціалу рослин у сучасній технології вирощування сої.

**Ключові слова:** соя, збудники хвороб, фунгіциди, передпосівна обробка насіння ефективність, урожайність.

**Табл. 4, Рис. 1, Літ. 18.**

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