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PREVALENCE AND HARMFULNESS OF ALTERNARIA LEAF SPOT AND DOWNY MILDEW OF SOYBEAN

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The article focuses on assessing the prevalence, intensity of development, and harmfulness of the major fungal diseases of soybean–Alternaria leaf spot (Alternaria spp.) and downy mildew (Peronospora manshurica)–in the Forest-Steppe of Ukraine. Phytosanitary monitoring conducted during the 2024–2025 growing seasons demonstrated that these pathogens are key determinants of the phytopathological condition of soybean agrocenoses. Alternaria leaf spot was characterized by the highest level of disease development (31.6%), while downy mildew reached 29.1%, indicating favorable environmental conditions for pathogen proliferation and a high risk of yield reduction.

Biometric and morphometric analyses revealed that pathogen infection leads to a statistically significant decrease in all principal structural components of soybean productivity. Diseased plants exhibited inhibited vegetative growth, reduced plant height, decreased pod number per plant, shortened pod length, fewer seeds per pod, and a lower 1000-seed weight. These changes reflect pronounced physiological dysfunctions caused by impaired photosynthetic activity, disrupted assimilate translocation, and suppressed generative organ development under phytopathogenic stress.

Field experiments confirmed the substantial economic impact of Alternaria leaf spot and downy mildew on soybean productivity. In untreated control plots, yield did not exceed 2.5 t/ha. Fungicide application significantly reduced disease severity and promoted yield formation. Revus Top showed the highest technical efficacy, reducing disease development by more than 80% and ensuring the maximum yield increase (up to 3.0 t/ha). Amistar Trio provided stable disease control and a significant yield response, whereas Superio demonstrated moderate protective effectiveness. A direct correlation between the level of disease suppression and yield improvement was established. The obtained results substantiate the necessity of implementing integrated disease management systems combining fungicidal protection with scientifically substantiated agronomic practices to ensure sustainable soybean production under increasing disease pressure and climate variability.

Key words: *soybean, Alternaria leaf spot, downy mildew, phytosanitary status, pathogens, biometric parameters, fungicides, integrated disease management, yield.*

Петров С.П., Горяінова В.В., Станкевич С.В. Поширеність і шкідливість альтернаріозу та пероноспорозу сої

Стаття присвячена оцінці поширеності, інтенсивності розвитку та шкідливості основних грибних хвороб сої – альтернаріозу (Alternaria spp.) та пероноспорозу (Peronospora manshurica) – у лісостеповій зоні України. Фітосанітарний моніторинг, проведений у період вегетації 2024–2025 рр., показав, що патогени є ключовими факторами, що визначають фітопатологічний стан агроценозів сої. Альтернаріоз листя характеризувався найвищим рівнем розвитку хвороби (31,6 %), тоді як пероноспороз досяг 29,1 %, що свідчить про сприятливі умови для розвитку збудників та високий ризик зниження врожайності. Біометричний аналіз засвідчив, що інфекція патогенів призводить до статистично значущого зменшення всіх основних структурних компонентів продуктивності сої. Уражені рослини відзначалися пригніченим вегетативним ростом, зменшеною висотою рослин, зниженням кількості бобів на рослині, скороченням довжини бобів, меншою кількістю насінин у бобах та зменшеною масою 1000 насінин. Ці зміни відображають виражені фізіологічні порушення, обумовлені зниженням фотосинтетичної активності, порушенням транспорту асимілятів та пригніченням розвитку генеративних органів під впливом патогенів. Польові дослідження підтвердили суттєвий економічний вплив альтернаріозу та пероноспорозу на продуктивність сої. У контрольних варіантах врожайність не перевищувала 2,5 т/га. Застосування фунгіцидів істотно зменшувало розвиток хвороб і сприяло підвищенню продуктивності та врожайності. Фунгіцид Ревус Топ продемонстрував найвищу технічну ефективність, пригнічуючи розвиток хвороб більш ніж на 80 % та забезпечуючи максимальне збільшення врожаю (до 3,0 т/га). Амістар Тріо забезпечив стабільний захисний ефект і значне підвищення врожайності, тоді як Суперіо проявив помірну ефективність. Було встановлено пряму кореляцію між рівнем пригнічення хвороб і приростом врожаю. Отримані результати підтверджують необхідність впровадження інтегрованих систем захисту рослин, що поєднують фунгіцидний захист із науково обґрунтованими агрономічними заходами, для забезпечення стійкого виробництва сої за умов зростаючого тиску патогенів і кліматичної мінливості.

Ключові слова: *соя, альтернаріоз, пероноспороз, фітосанітарний стан, патогени, біометричні показники, фунгіциди, інтегрована система захисту, врожайність.*

Statement of the problem. Soybean is one of the most important leguminous crops worldwide due to its high protein and oil content. However, soybean production is significantly constrained by fungal and oomycete diseases, among which Alternaria leaf spot and downy mildew are particularly widespread. These diseases negatively affect plant growth, reduce photosynthetic activity, and lead to considerable yield losses and deterioration of seed quality.

In recent years, changes in climatic conditions and agricultural practices have contributed to an increase in the prevalence and harmfulness of Alternaria leaf spot and downy mildew in soybean agroecosystems. Despite the economic importance of these diseases, comprehensive data on their distribution, intensity of development, and harmful effects under specific regional conditions remain insufficient. This lack of up-to-date information limits the effectiveness of disease management strategies and the development of integrated plant protection systems.

Therefore, there is a need for detailed research on the prevalence and harmfulness of Alternaria leaf spot and downy mildew of soybean to improve monitoring, forecasting, and control measures and to ensure stable soybean production.

Analysis of recent researches and publications. Over the past decade, extensive research in Ukraine and globally has focused on the biology, pathology, and protection of soybean (*Glycine max* L.) crops. Ukrainian studies emphasize the prevalence and management of fungal diseases, as well as the implementation of integrated pest and disease management strategies.

Kyryk et al. [1, p. 96-98] and Pasichnyk et al. [2, p. 10-16] provided detailed analyses of soybean diseases, highlighting methods for diagnosis, peculiarities of disease

development, and protective measures in local agronomic conditions. Vdovychenko and Bilyk [3, p. 17-20] and Kharchenko [4, p. 82-88] focused on soybean morphology, physiology, and its role in agricultural systems, emphasizing the importance of plant health for yield optimization. Kovalchuk [5, p. 42-46] and Trybel [6, p. 110-112] offered practical and theoretical frameworks for agronomic management and testing of protective measures, providing guidance for field applications.

Research by Nevmerzhytska [7, p. 90–94] demonstrated the effectiveness of soil herbicides in controlling weeds and indirectly mitigating disease incidence, while modern integrated management approaches in the United States [8, p. 17] highlight strategies for adapting soybean disease control to changing climatic conditions.

Recent studies Sergiienko [9, p. 18-23; 10, p. 9-11] examined the effect of fungicides on disease development and yield, confirming the importance of chemical protection alongside agronomic practices

Monitoring studies [11, p. 88-92; 12, p. 256-261; 13, p. 9-11]; revealed that diseases such as *Alternaria* leaf spot, downy mildew, and Fusarium root rot remain highly prevalent in Ukrainian soybean crops, particularly in the Forest-Steppe regions.

Despite substantial progress, gaps remain in understanding the combined effects of environmental stressors, modern pesticides, and biological control methods on disease development.

In conclusion, recent research in Ukraine reflects a growing emphasis on integrated disease management, the use of adaptive cultivars, and optimization of agronomic practices. However, there is a clear need for further studies on the combined effects of chemical, biological, and cultural controls in diverse agroecological zones, as well as on the economic implications of disease management strategies.

Objective. The primary objective of this study is to comprehensively assess the prevalence, pathogenicity, and economic impact of *Alternaria* leaf spot and downy mildew in soybean (*Glycine max* L.) crops. This includes identifying the main causal agents, evaluating the conditions favoring disease development, and analyzing both chemical and biological methods of disease control. The ultimate aim is to provide scientifically grounded recommendations for the implementation of integrated protection strategies that enhance soybean productivity.

Materials and methods. The study was conducted in experimental fields in the Forest-Steppe of Ukraine using commonly cultivated soybean (*Glycine max* L.) varieties [2, p. 18-22; 6, p. 24-28; 7, p. 90-94]. Field surveys were carried out during the 2024–2025 growing seasons to assess the prevalence and severity of *Alternaria* leaf spot and downy mildew, using standard phytopathological methods [14, p. 126-128; 16, p. 320-326]. Infected plant samples, including leaves, stems, and seeds, were collected and examined in the laboratory for pathogen identification based on morphological characteristics and mycological techniques [14, p. 130-132; 16, p. 328-3232]. Field experiments evaluated chemical fungicides, biological control agents, and cultural practices such as sowing dates, crop rotation, and plant density to reduce disease incidence [17, p. 156-160; 18, p. 202-208]. Treatments were arranged in randomized complete block designs with three replications, and standard agronomic practices were applied [5, p. 14-16; 19, p. 212-218]. Disease assessments were performed at key growth stages, and yield parameters, including pod number, 1000-seed weight, and total grain yield, were recorded. Data were statistically analyzed using correlations between disease severity and yield loss were determined to assess the economic impact of infections [20, p. 16-20].

Summary of the main research material. The analysis of diseases development indicators indicates that the leading pathogens affecting the phytosanitary condition of

soybean crops are *Alternaria* leaf spot and downy mildew. *Alternaria* leaf spot exhibited the highest level of development at 31.6%, highlighting its dominant role among foliar infections. Downy mildew ranked second with a development level of 29.1%, confirming its significant impact on the overall plant infection rate (Fig. 1).

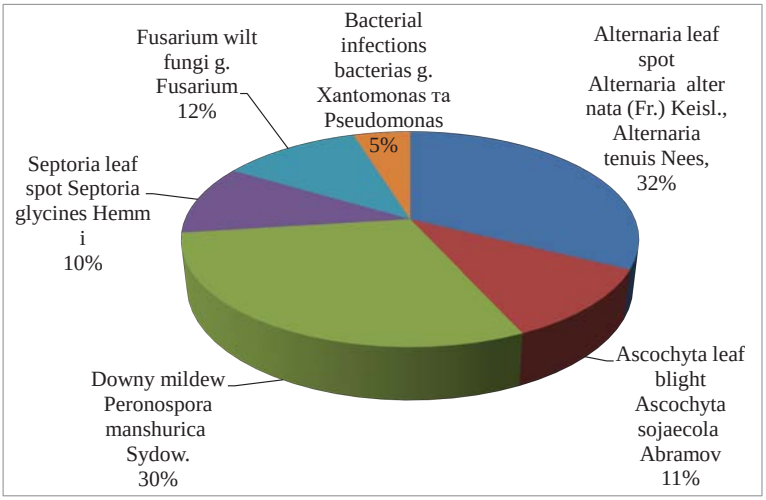

Figure 1. Monitoring of major soybean diseases

Fusarium wilt and *Ascochyta* infections were less intensive (11.4% and 10.6%, respectively), but their presence can adversely affect the physiological condition of plants, especially under stressful environmental conditions. Septoria infection showed a similar prevalence level of 10.3%, indicating the stable presence of this pathogen within the agrocenosis.

Bacterial infections (*Xanthomonas*, *Pseudomonas*) accounted for the smallest share in the disease structure at only 4.7%, suggesting their episodic occurrence. Thus, the phytosanitary condition of soybean crops is primarily determined by fungal diseases, with downy mildew and *Alternaria* leaf spot posing the greatest threat. This underscores the need for appropriate preventive and protective measures to limit their spread and harmful effects.

Assessment of the phytosanitary condition of soybean plants and analysis of biometric parameters of healthy and infected specimens indicate a significant negative impact of two primary pathogens – downy mildew (Peronospora manshurica) and alternaria leaf spot (Alternaria spp.). Experimental data reveal a pronounced reduction in all structural components of yield, reflecting the complex physiological and morphological detrimental effects characteristic of these diseases (Table 1).

Table 1

Influence of diseases on the structural elements of soybean productivity

Parameter	Healthy	Infected	Deviation (±)
Plant height, cm	170	150	–20
Average number of pods per plant, pcs	305	260	–45
Average pod length, cm	12,0	9,0	–3,0
Average number of seeds per pod, pcs	30	22	–8
1000-seed weight, g	4,3	3,1	–1,2

Biometric analysis shows that infected plants significantly underperform compared to healthy plants across nearly all parameters. A reduction in plant height by 20 cm indicates substantial suppression of vegetative growth, associated with impaired photosynthetic activity and overall depletion of the plant organism under pathogen pressure. The most pronounced changes are observed in the formation of generative organs: the number of pods per infected plant decreased by 45 pcs, which critically reduces productivity. Such marked declines in reproductive potential are caused both by direct damage to leaf surfaces and by disruptions in assimilate transport and trophic processes.

Deterioration of yield quality is confirmed by a reduction in average pod length by 3 cm and a decrease in the number of seeds per pod by 8. These indicators reflect insufficient pollination, incomplete ovule development, and underdeveloped seeds due to prolonged pathogen exposure. The decrease in 1000-seed weight by 1.2 g indicates impaired seed filling and formation of underdeveloped, lightweight seeds, negatively affecting sowing quality and the potential of subsequent generations.

The harmful effects of downy mildew are associated with rapid infection of the leaf surface, impaired gas exchange, and substantial loss of photosynthetic capacity. Typical formation of chlorotic spots and sporulation on the abaxial leaf surface leads to premature leaf senescence and abscission. This disrupts the balance of growth processes and reduces overall biological productivity.

Alternaria leaf spot, exhibiting necrotic lesions, results in dark, deep spots that destroy leaf and stem tissues. Necrosis accelerates the loss of functional leaf area and creates conditions for secondary infections. This pathogen exerts chronic stress on the plant, manifested in growth inhibition, reduced reproductive activity, and decreased seed quality.

Thus, downy mildew and alternaria leaf spot are critical factors reducing soybean productivity, affecting all stages of ontogeny – from disruption of photosynthesis and growth processes to degeneration of generative structures and deterioration of seed quality. The development of these pathogens can lead to significant economic losses, emphasizing the necessity of implementing integrated disease management systems aimed at early detection, prevention, and limiting disease spread.

Analysis of the phytosanitary condition of soybean crops indicates a growing need to improve crop protection systems against disease pathogens. Achieving high efficiency of phytosanitary measures requires a scientifically substantiated selection of fungicidal products and a rational combination of organizational, economic, and agronomic practices. Such an integrated approach ensures the most complete realization of the yield potential of soybean varieties and hybrids.

Under field conditions, a significant development of Alternaria leaf spot (31.6%) and downy mildew (29.1%) was observed in the untreated control, indicating favorable conditions for the development of these diseases and their potentially negative impact on soybean yield.

Among the tested fungicides, Revus Top demonstrated the highest efficacy, reducing alternaria leaf spot incidence to 5.6% and downy mildew to 3.9%, which corresponded to high levels of technical efficiency (82.3% and 86.6%, respectively). Amistar Trio provided substantial suppression of disease development (Alternaria leaf spot – 8.5%, downy mildew – 7.8%) with a technical efficiency of approximately 73%, resulting in increased crop productivity compared to the control. Superio exhibited moderate efficacy, limiting disease development to 10.2% for Alternaria leaf spot and 8.5% for downy mildew.

In the untreated control, soybean yield was 2.5 t/ha for both diseases, reflecting the negative impact of Alternaria leaf spot and downy mildew on crop productivity.

Fungicide application had a positive effect on yield formation. Revus Top ensured the highest yield increase, reaching 3.0 t/ha under alternaria leaf spot pressure and 2.8 t/ha under downy mildew infection, which correlates with the highest level of disease suppression. Amistar Trio increased yield to 2.9 t/ha and 2.6 t/ha under Alternaria leaf spot and downy mildew, respectively, demonstrating stable protective action and a positive effect on productivity.

Superio provided a moderate yield increase to 2.85 t/ha under alternaria leaf spot and 2.7 t/ha under downy mildew, reflecting partial disease control.

Thus, the application of systemic and combined fungicides not only effectively suppresses disease development but also significantly enhances soybean yield, particularly under conditions of high risk of Alternaria leaf spot and downy mildew infection.

Conclusions. Phytosanitary monitoring confirmed that Alternaria leaf spot and downy mildew are the dominant soybean diseases, with development levels of 31.6% and 29.1%, respectively. Infection by these pathogens caused a significant reduction in biometric and yield components, leading to yield limitation to 2.5 t ha^{-1} in untreated control plots.

Fungicide application significantly suppressed disease development and improved productivity. Revus Top showed the highest technical efficiency (>80%), ensuring the maximum yield increase up to 3.0 t/ha, while Amistar Trio and Superio provided stable to moderate control. A direct relationship between disease suppression and yield formation was established.

The results confirm the necessity of integrated disease management to reduce the harmfulness of Alternaria leaf spot and downy mildew and to ensure stable soybean production under increasing phytopathological pressure.

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