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THE EFFECTIVENESS OF FUNGICIDAL PROTECTION OF SOYBEAN IN THE CONDITIONS OF THE RIGHT-BANK FOREST-STEP

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This article presents the results of studies on the effect of double application of fungicides on the development of major diseases in soybean crops, as well as on the efficiency indicators of crop cultivation. According to the results of phytopathological monitoring in the soybean agrocenosis in the Vinnytsia region, conducted in 2023-2024, the species composition of soybean disease pathogens was established during the research. Septoria (Septoria glycines Hemmi.) – 24% and Alternaria tenuis Nees. – 21% were the dominant fungal diseases. Fusarium wilt (Fusarium oxysporum Schecht.) – 19%, Peronosporosis (Peronospora manshurica Sydow.) – 18% and cercosporosis (5%) were less common. The lowest level of damage was observed with powdery mildew (4%) and Ascochitosis (Ascochyta sojaecola Abramov.) – 3%. In addition, the share of bacterial diseases was 4%, and viral diseases – 2%.

Research has established that the technical efficiency of two-time spraying of soybean plants against the main diseases was 65% – 82%. The highest efficiency was recorded in the fight against peronosporosis. Among the applied drugs, the best results were demonstrated by Aliette, 80% *w. p. and Abacus, CE c.e. fungicides, which provided 78–82% protection of plants from the main diseases. The average soybean yield in the experimental variants ranged from 3,32 t/ha in the control to 2,96 t/ha in the best yield variant with the use of the fungicides Aliette,* 80% *w. p. agronomic and Abacus, CE c.e. agronomic for disease protection. The yield increase was 0,50–0,64 t/ha compared to the control. Conditionally net profit ranged from 25,844 UAH/ha in the control variant to 27,749 UAH/ha in the variant with the highest crop yield (Aliette,* 80% *w. p. + Abacus, CE c.e., and the profitability level was 115% in the variant using fungicides Aliette,* 80% *w. p. and Abacus, CE c.e., which showed the best result.*

Key words: *soybean variety Titan, main soybean diseases, modern fungicides, lesions, disease development, efficiency, yield, profitability*

Table 3. Fig 1. Lit. 22.

Introduction. Today, soybean is one of the most widespread and important agricultural crops in the world. It is grown on extensive fields in various countries, including the USA, Brazil, Argentina, China, India, and Ukraine.

For many years, soybean has occupied one of the key places in the agricultural market of Ukraine. It plays an important role in ensuring food and economic security of both our state and European countries. The area under soybean crops is increasing almost every year, and today Ukraine is among the ten leading global producers of this crop [1].

Soybean is a multifunctional plant with food, feed, agricultural and technical applications. Its popularity is due to the high protein content in the seeds – from 35 to 50%. Soy protein contains a significant amount of essential amino acids, in particular lysine, methionine and cysteine. In addition, soy contains about 20% fat, most of which is unsaturated fatty acids.

A feature of soybean is its ability to symbiosis with nitrogen-fixing bacteria, in particular with microorganisms *Rhizobium japonicum*, which contributes to the enrichment of the soil with nitrogen, which is accumulated by the plant from the air and is practically free. The number and shape of colonies of nodular bacteria on the root system depend on the strain, virulence of microorganisms, as well as growing conditions [4, 5].

Soybean cultivation in Ukraine has significant potential for further development, in particular through the expansion of sown areas and the introduction of modern high-yield agricultural technologies. However, these measures alone cannot fully overcome the existing problems faced by agricultural producers. To achieve high production results, it is necessary to focus efforts on increasing yields, which involves not only the introduction of innovative elements of agricultural machinery, but also the comprehensive and optimal use of existing technological solutions [3].

Ukraine is demonstrating significant progress in soybean cultivation, increasing both the sown area and the gross harvest. In 2020, the gross soybean harvest reached a record level of 4,247 thousand tons, which was made possible by the expansion of the sown area to 2,200 thousand hectares. This is the highest figure in the history of growing this crop in Ukraine [3, 4, 6].

According to the Ministry of Agrarian Policy, in the war year 2022, domestic farmers harvested soybeans from an area of 1,5 million hectares, threshing 3,7 million tons. Compared to the previous, peaceful year, the area under the crop increased by 4%. This indicates that even in wartime conditions, certain hopes were placed on soybeans as a promising and important agricultural crop [2, 3].

The growth of sown areas and the cultivation of soybeans in monoculture lead to a deterioration of the phytosanitary condition of agrocenoses and necessitate the search for an effective system of protection against harmful organisms. During the growing season, soybean plants are affected by pathogens of various taxonomic affiliation, which can significantly reduce productivity and crop quality. In some years, crop losses due to diseases reach 40–70% or more. Non-compliance with crop rotation, long-term cultivation of soybean as a monoculture (more than two years), and other factors contribute to the annual accumulation of infectious material in the soil and seed material, which creates favorable conditions for its spread and dominance [5].

Soybean is affected at different stages of growth and development depending on the type of pathogen causing the disease and the growing conditions. Over 100 types of pathogens can cause significant damage to soybean crops, reducing their quality and yield.

Therefore, agricultural producers, in particular farmers, are faced with the task of minimizing crop losses from harmful organisms, including diseases, by introducing and improving the study of the effectiveness of modern fungicides to protect soybean plants from diseases.

Analysis of recent research and publications. In recent years, there has been an increase in damage to soybeans by phytopathogenic micromycetes, which is caused by a number of factors: the import of infected seeds, violation of crop rotation, and non-compliance with the optimal sowing dates. The consequences of infection are a decrease in the energy of germination, viability and field germination of seeds. The use of infected seed material contributes to the preservation and spread of pathogens throughout the entire agro-technological cycle – from vegetation to harvest storage. Diseases lead to liquefaction of crops, weakening of plants, reduction of photosynthetic activity, deterioration of product quality and reduction of overall productivity [13].

Infection by pathogenic microorganisms leads to a decrease in the sowing qualities of seeds and negatively affects the quality of plant products, which complicates their further processing and consumption. This is due to the contamination of the waste products of pathogens – metabolites that can be toxic to human and animal health. Diseases caused by fusarium toxins are especially dangerous, which in recent years have become globally widespread and have become a serious challenge for agriculture throughout the world [8].

Research has established that more than 25 diseases of fungal origin are systematically detected in the agrocenosis of soybeans, which lead to the deterioration of the quality of the seed material, the reduction of yield and indicators of product quality. The vast majority of pathogens are pathogenic fungi that cause fusarium wilt, alternaria wilt, peronosporosis, septoria wilt, ascochyta wilt, white rot and other diseases. Bacterial and viral diseases are much less common [9, 10].

Also, it should be noted that bacterial diseases occur in soybean crops: bacterial burn, bacterial wilt, wartiness. In soybeans, several viral diseases are detected – these are wrinkled mosaic and yellow mosaic.

Affected seeds pose a serious threat to the phytosanitary condition of crops, especially seed crops, as they can become a source of infection for new plants. Under favorable conditions and the expansion of soybean crop areas, this can lead to epiphytotia – a mass spread of bacterial diseases.

Fusarium wilt (*Fusarium oxysporum* Schecht.) is one of the most dangerous and harmful diseases of soybeans. The disease is found in all regions of soybean cultivation both in the seedling phase and on adult plants. The causative agents are fungi of the genus Fusarium spp. The main forms of manifestation of the disease: root rot in seedlings and adult plants, fruit and seed rot, tracheomycosis – damage to the vascular system of plants during flowering and fruit formation. The affected seeds shrivel, lose their viability and ability to germinate normally.

Symptoms of fusarium wilt on soybean seedlings include uneven thickening and deformation of seedlings, deep brown ulcers with a pink bloom on the cotyledons and the formation of pink pads – this is the sporulation of the fungus. In the phase of budding and bean formation, yellowing, wilting, leaf fall, darkening of the stem in the root collar area (dark brown color), which causes general wilting of the plant. Sources of infection are affected soil and plant debris (especially without crop rotation) [7, 11].

Most species of the genus Fusarium are saprophytes, but under certain conditions they are able to switch to a parasitic lifestyle. The negative impact of fusarium wilt on soybean can be partially limited by treating seeds with fungicides, increasing the seeding rate, and stimulating plant branching. Fusarium pathogens are usually localized in the intercellular spaces of plant tissues, causing cell maceration. On seeds, the pathogen is mainly contained in the shell, but often penetrates the epidermis and even into the embryo. The species Fusarium oxysporum also affects the vascular system of plants, causing its blockage and intoxication, which ultimately leads to wilting of the plant [7, 8, 13].

Alternaria tenuis Nees, a decrease in the assimilation surface of leaves, which leads to their premature drying and death. As a result, soybean seed productivity is significantly reduced. Yield losses of this crop can reach 20% or more.

The optimal conditions for the development of the causative agent of alternariosis are the presence of a significant amount of moisture, which ensures its parasitism, and also indicates its temperature tolerance. The main sources of infection are plant debris and soil. The disease spreads during the growing season by conidia. The most favorable conditions for the germination of conidia and infection of plants are a temperature of +20–26°C, high relative humidity (over 95%), the presence of droplet moisture and reduced plant immunity [8, 9].

Ascochitosis (*Ascochyta sojaecola* Abramov.) is a widespread disease in all areas of soybean cultivation. The causative agent of the disease is the fungus Ascochyta. Symptoms of soybean ascochitosis blight, caused by a fungus of the genus Ascochyta, are the appearance of yellowish-brown spots on the leaves. Sometimes the center of the spot falls out, holes form in the leaves. Black spots form on the beans, and the spots on the beans are gray, they can turn into deep brown ulcers with numerous pycnidia (spore-bearing structures of the fungus). With severe damage, the leaves of the beans become whitish, covered with a large number of pycnidia. The seeds in such beans either do not form or rot. In severe cases, the disease can lead to the death of the plants [10].

Temperature +20–25 °C is the optimal temperature range for the germination of pycnospores. Under such conditions, the pathogen becomes active, which contributes to the development of the disease. The presence of droplet moisture is very important, since water is necessary for the germination of spores and penetration into plant tissues. The preservation of the pathogen in plant debris and seeds are the main sources of infection. Mycelium and pycnidia with pycnospores can overwinter and provide primary infection of the new crop [8, 9].

Peronosporosis is a fungal disease caused by the oomycete fungus *Peronospora manshurica* Sydow, which is an obligate biotroph. The pathogen survives in the soil, on plant debris, and in seeds, which contributes to the widespread spread of infection.

The lesion can be: primary – occurs as a result of seed infection. Usually occurs at high soil moisture during seed germination. The mycelium of the fungus develops simultaneously with the plant, spreads quickly and causes diffuse lesions. When visible signs of the disease appear on the cotyledonous or true leaves, the plant is very difficult to save, because all organs are affected. Such plants usually lag behind in growth (dwarf) or die [11, 19,].

Secondary the lesion occurs by the causative agent of peronosporosis, when the pathogen is really activated during sharp temperature drops between day and night, as well as high humidity, which creates a favorable environment for its development. Manifestations of the disease can appear already from the 4–6 leaf phase, and accompany the plant until the ripening phase. Typically, characteristic yellow or pale green spots appear on the leaves, which eventually acquire a brown tint, and a white-gray coating forms on the underside of the leaf – these are the spore-bearing structures of the pathogen. This disease can reduce yields by up to 50%, and the weight of 1000 seeds can decrease by 6% or more [19].

Septoria (*Septoria glycines* Hemmi.) is a common soybean disease that occurs throughout Ukraine, although it is most often recorded in the Polissya zone. The pathogen is the fungus *Septoria glycines* T. Hemmi. The most intense development of the disease takes place in the period from flowering to the beginning of the formation of beans.

The pathogen of *Septoria glycines* actively develops at temperatures from +5 to +36°C, with optimal indicators of +22…+28°C and high relative humidity (80–100%). The main sources of infection are infected seeds and plant residues, on which pycnidia with pycnospores are formed, which infect leaves during the growing season [20].

Mass the lesion to plants is caused by increased average daily temperatures, heavy rains in the second half of July and August, as well as the presence of dew on the leaves. The harmfulness of septoriosis is due to the reduction of the assimilation surface of plants, because up to 50% of the leaves can dry up and die prematurely. This, in turn, leads to crop losses that can reach 15–30% [8, 11].

Anthracnose is spread by conidia during vegetation. Increased development of the disease is observed at air humidity of at least 60% and temperature +15–19°C. Small spots with a brown border appear on the affected beans, which in wet weather become covered with conidial sporulation.

The sources of infection are the remains of plants and seed material, in which the pathogen is stored in the form of mycelium. The harmfulness of the disease consists in liquefaction of seedlings – most of the plants die before they emerge to the surface. Anthracnose also reduces the sowing quality of seeds, limits the potential of plants and reduces the productive area of leaves [9, 13].

Cercosporosis of soybean. The marsupial fungus *Whetzelinia sclerotiorum* (dBy.) Korf. et Dumont is the pathogen. It manifests itself in the form of small lesions, which are usually localized on the upper part of the leaf blade. The spots have an irregular shape and color, which varies from grayish, red-brown to purple.

Prolonged and intense precipitation contributes to the progression of the disease. With severe damage, leaf tissue detachment may be observed.

At the ladder stage, the degree of damage can reach 52–97%. Although infected young plants usually do not die and continue to grow, their productivity is significantly reduced: yield drops by 2–3 times, fat content decreases by 2–7%, and protein by 4–5%. In addition, the assimilation surface of the leaves decreases, which negatively affects photosynthetic activity [8, 10].

To equalize or reduce the impact of diseases of fungal origin on soybean plants, it is necessary to use plant protection products, among which the use of fungicides is one of the most effective. Modern fungicides are highly effective chemical compounds that affect specific biochemical processes, in particular, the synthesis of sterols, the mitochondrial respiratory chain, or fungal cell division. Due to their targeted action, they provide high efficiency even at low rates of consumption, which allows not only to reduce economic costs, but also to minimize the impact on the environment [1].

However, the use of synthetic fungicides comes with a number of problems. In particular, there are risks for deterioration of the human condition, negative impact on water ecosystems, reduction in the number of beneficial soil microflora, and in some cases – destruction of the ozone layer. According to S.V. Retman et al. [20], frequent and irrational use of fungicides leads to the formation of pathogen populations resistant to them.

The effectiveness of fungicides largely depends on the phase of crop development during which they are applied, as this determines their ability to suppress pathogens and reduce crop losses. At the same time, the effectiveness of fungicides can be negatively affected by various factors, in particular, adverse weather conditions or the use of drugs on genetically resistant soybean varieties to pathogens. As a result of such conditions, a paradoxical effect may occur – an increase in crop losses despite the use of fungicides [12].

Although fungicides are widely used to control soybean diseases worldwide, there is still no clear understanding of the optimal duration of their application. Different countries apply fungicides based on different criteria. The most common approach is to apply at specific growth phenophases. This method is based on crop phenology and does not require disease diagnosis, making it convenient to use [13].

According to M. B Hrabovskyy., O. V. Mostypan [17], the use of fungicides contributed to an increase in soybean grain yield by 11–15%. Similar results regarding the positive effect of fungicides on soybean productivity are given in the works of other researchers.

The use of chemical preparations Abacus and Renengo and biological agents Pseudobacterin-2 and Baktofit in the soybean protection system contributed to maintaining grain yield at the level of 0,27–0,42 t/ha.

In the context of measures to protect soybeans from seed-borne pathogens, the use of fungicides plays an important role. Seed treatment with fungicides effectively destroys pathogens on its surface, as well as protects seedlings from soil-borne pathogens in the initial stages of growth [14].

Among the drugs that are compatible with nodule bacteria, the most effective are: Fever, 300 FS, (0.2–0.4 l/t), Maxim XL 035 FS (1.0 l/t), Vitavax 200 FF, 34%, and others. The rational combination of all means of optimizing symbiotic processes contributes to the formation of an effective symbiotic apparatus, improves the phytosanitary condition of crops, increases soil fertility and ensures a consistently high soybean yield with excellent quality indicators [15].

Research has shown that fungicides have different effects on the inoculation activity of rhizobia in symbiosis with soybeans. In particular, the fungicide Fever and Standac Top in the phase of two true leaves slightly inhibit inoculation, but in the phases of three true leaves and budding – stimulate the formation of nodules and nitrogen fixation. The use of the fungicide Akanto Plus, according to the results of field experiments, has a positive effect on symbiosis, contributing to an increase in seed weight by 21% compared to the control [14, 19].

The highest soybean yield in the conditions of the Western Forest-Steppe of Ukraine was obtained by using the fungicide scheme: *Aliette*, 80% w. p. of the yield at the rate of 1,5 kg/ha and Propuls, 25% of the effective yield at the rate of 0,8 l/ha. In this variant, the yield was 37,5 c/ha, which was 11,0 c/ha higher than the control variant. The fungicides used demonstrated high biological efficiency against the main diseases of soybean: over 80% against septoria, cercospora and fusarium, 78% against peronospora and ascochyta, 65% against powdery mildew. The results obtained indicate the feasibility of using this fungicide protection scheme to ensure a consistently high soybean yield and reduce the phytopathological load in the conditions of the Western Forest-Steppe [16].

According to L. I. Rybachenko [18], two-time application of the fungicides Koronet (0,6 l/ha) and Abacus (1,5 l/ha) in the phases of the beginning of budding and the end of flowering contributed to achieving the highest soybean yield – 2.70 t/ha, as well as the maximum protein content in seeds – 37,8%.

The use of fungicides – Amistar Extra 280 SC, Akanto Plus 28 KS, Bumper Super 490 KE, Koronet 300 SC, Impact K c.s. in soybean crops in the Forest-Steppe of Ukraine against the background of pre-sowing seed treatment with the inoculant Rizoaktiv significantly improves the physiological processes of plants. These fungicides contribute to an increase in the leaf surface area by 20–48%, an increase in the net productivity of photosynthesis by 7–9%, an increase in the content of chlorophylls a and b in leaves by 58–79%. This indicates an activation of growth and photosynthetic processes, which ultimately can positively affect the yield and resistance of soybeans [55, 16].

Yield losses and the intensity of disease development in soybean agrophytocenoses indicate that reducing the harmfulness of diseases and increasing the competitiveness of plants is an important reserve for increasing the productivity and economic efficiency of soybean production. Therefore, scientific substantiation and the search for effective ways to optimize the fungicidal protection of soybean crops remain an urgent task of modern agronomy.

Materials and methods of research. The research was conducted in 2023–2024 in the conditions of the Vinnytsia region, the species structure of soybean disease pathogens and the use of protective measures to limit their development were studied, according to generally accepted field research methods adopted in phytopathology [20, 21].

The experiments used the variety Titan (originator of the Institute of Feed and Agriculture of Podillia NAAS of Ukraine). The predecessor was winter wheat.

The experimental plots were placed on an area of 10 m² in a randomized manner with four replications.

Accounting of plants and observations. To determine the species structure of the main diseases in each experimental plot, a visual inspection of 20 plants was carried out at four different recording points. In each of the selected places, the degree of plant affected by disease by each disease was assessed. Assessment of disease development and spread in field conditions was carried out in the phases of the first pair of true leaves (BBCH 13) and flowering (BBCH 64–66). The studies used fungicides of different classes of chemical compounds and with different mechanisms of action, in accordance with the «List of pesticides and agrochemicals permitted for use in Ukraine», in compliance with the established regulations for their use [22] (Table 1).

In order to determine the effect of the studied fungicides on the development of soybean diseases, affected was recorded before spraying (the rate of consumptio+of the working liquid is 250 l/ha), as well as 7 and 15 days after it. At the same time, 60 plants were examined in each experimental plot (20 plants in three observation locations), on which the degree of damage by each disease was determined.

Table 1

Scheme of an experiment to assess the effectiveness of fungicides for spraying soybean crops against major diseases

Variant	Phase of application	
	BBCH 13	BBCH 64-66
I (Control)	(without drugs)	(without drugs)
II	*Aliette*, 80% w. p. (*fosetyl aluminum*, 800 g/kg), 2,0 kg/ha	Abacus, CE (*pyraclostrobin*, 62,5 g/l + *epoxyconazole*, 62,5 g/l), 1,5 l/ha
III		Propulse 250 SE, c.e.(*fluopyram, 125 g/l and + prothioconazole, 125 g/l*), 1,0 l/ha
IV		Amistar Extra 280 SC c.s (*cyproconazole, 80 g/l* + *azoxystrobin, 200 g/l*), 0,75 л/га

source: formed on the basis of own research

The development of the disease (R) was determined based on the results of the examinations and the generally accepted formula:

$$R=\Sigma(A\times B)/K\times N\times 100, \qquad (2.1)$$

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

B – is the score corresponding to these symptoms;

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

K – is the total number of examined plants;

N – is the highest score of plant affected by disease according to the assessment scale [21].

The technical efficiency of fungicides was calculated according to formula 2.2:

Te = 100 (Ав – Ва) / Ав,…………........……….(2.2)

Te – technical efficiency %;

Ав – disease development indicator in the control;

Ва – disease development indicator in the experimental variant [21].

In the phase of full ripeness of soybean grain, harvesting was carried out by direct combining. Harvest accounting was carried out by weighing the grain collected from the accounting area, with subsequent conversion of indicators to standard conditions – 14% moisture and 100% purity.

The mass of 1000 seeds was determined by weighing two samples of 500 seeds with an accuracy of 0,1 g, after which the obtained values were summed up. Statistical processing of experimental data was performed using the «Statgraphic plus» computer program.

Research results. As a result of the research conducted in Vinnytsia region on soybean crops in the control variant, where fungicides were not used, pathogens of fungal, bacterial and viral origin were detected. It was established that the species diversity of fungal diseases was represented by septoria, alternaria, peronosporosis, fusarium wilt, cercosporosis and ascochytosis, and among bacteriosis, bacterial burn was noted. In a small number, isolated manifestations of viral infections on plants were recorded**.**

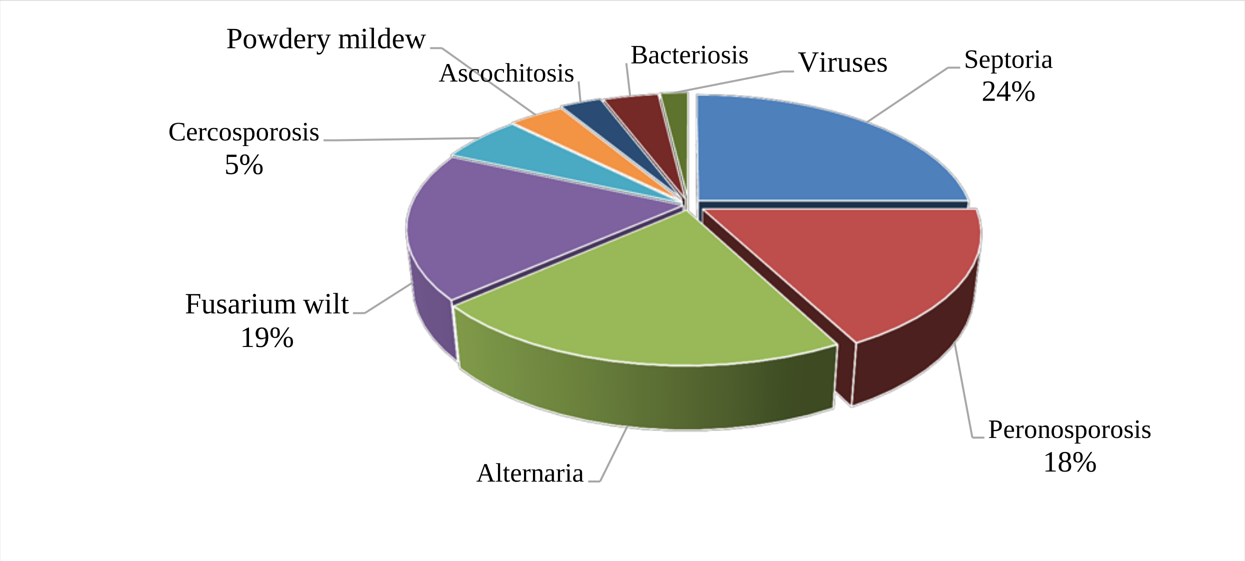

Fig. 1 Species structure of soybean diseases (Vinnytsia region, 2023-2024).
source: formed on the basis of own research

Based on the obtained data on the species diversity of soybean diseases, further observations of the dynamics of their development and the influence of fungicides were carried out for the dominant diseases: septoria, alternariosis, fusarium and peronosporosis. Their development occurred gradually, while the highest level of damage was observed in septoriosis and alternaria.

The technical efficiency of fungicides is defined as the reduction in disease development on treated plants compared to the control variant in which fungicides are not used. Determining technical efficiency allows us to assess how effectively the preparation prevents the development of diseases. This indicator also allows us to assess how well the fungicide copes with the infection, compared to if the treatment was not carried out. The higher the percentage of efficacy, the more the fungicide reduces the development of diseases.

As a result of studies conducted to study the effect of two-time application of fungicides affecting the development of soybean diseases in the conditions of the Vinnytsia region, the technical efficiency of the studied drugs ranged from 65 to 82% (Table 2).

Table 2

Technical efficiency, (%) of fungicides in soybean crops, average for 2023-2024

Variant	Disease							
	Peronosporosis		*Alternaria*		*Septoria*		*Fusarium* wilt,	
	R, %	E_t, %	R, %	E_t, %	R, %	E_t, %	R, %	E_t, %
Control (without drugs)	9,4	-	12,5	-	14,2	-	10,7	-
Aliette, 80% w. p. + Abacus, CE	1,7	82	3,0	76	3,1	78	3,1	71
Aliette, 80% w. p. + Propulse 250 SE, c.e	1,9	80	2,7	78	3,4	76	3,4	68
Aliette, 80% w. p. + Amistar Extra 280 SC	2,1	78	3,2	74	3,9	73	3,7	65

Note: R – disease development, %; Et – technical efficiency, %
source: formed on the basis of own research

It was noted that the highest indicators of technical efficiency against the main diseases of soybeans were achieved in the variant of treatment using the fungicide *Aliette*, 80% w. p. for the first spraying in the phase of BBCH 13 and Abacus (12,5% s.e.) for the second spraying in the phase of BBCH 64-66, which amounted to 71–82%. This ensured maximum efficiency in disease control.

The lowest technical efficiency was observed when using *Aliette*, 80% w. p. for the first spraying and Amistar Extra 280 SC for the second spraying of soybean plants. This indicates that the combination of these drugs was less effective, probably due to different effects of the drugs on the plants or the specificity of the diseases that were affected.

According to the results of a study of the effectiveness of drugs for protection against various diseases, it was noted that the highest effectiveness was found against downy mildew (78-82%), and the lowest against *Fusarium* wilt (65-71%).

So, as a result of research into the technical efficiency of spraying soybean plants against diseases using various fungicides in 2023-2024 in the Vinnytsia region, the overall level of efficiency of double spraying was from 65% to 82%. The best results were observed in the fight against downy mildew, and the most effective fungicides were *Aliette*, 80% w. p. (2,0 kg/ha) and Abacus, CE, c.e. (1,5 l/ha) in protecting plants from major diseases – 78-82%.

The goal of improving any element of cultivation technology is its impact on increasing crop yields. This approach is based not only on the effectiveness of fungicides, but also on their impact on the overall productivity of the agricultural system. Assessing not only technical efficiency, but also how the drugs contribute to crop preservation, allows for the creation of comprehensive recommendations for farmers. This allows not only to improve plant quality and reduce losses from diseases, but also to ensure a more stable and larger harvest, which is important for the economic efficiency of agricultural production.

As a result of two-time spraying of soybean plants of the Titan variety in the conditions of the Vinnytsia region, an increase in yield was reliably recorded compared to the control variant. It was noted, according to the results of two-year studies, that the average soybean yield in the experimental variants ranged from 2,82 to 2,96 t/ha, while in the control variant it was 2,32 t/ha. The highest yield – 2,96 t/ha – was provided by the variant with the use of the fungicides *Aliette*, 80% w. p. (2,0 kg/ha) and Abacus, CE (1,5 l/ha), which exceeded the control indicator by 0,64 t/ha (Table 3.).

Table 3

Economic effectiveness of the use of fungicides in soybean crops (average for 2023-2024)

Variant	Weight of 1000 seeds, g	Yield, t/ha	Yield increase t/ha
Control (without drugs)	150,0	2,32	-
Aliette, 80% w.p. + Abacus, CE	159,2	2,96	0,64
Aliette, 80% w.p. + Propulse 250 SE, c.e	158,6	2,87	0,55
Aliette, 80% w.p. + Amistar Extra 280 SC	157,7	2,82	0,50
$LSD_{0,5}$	-	*1,08*	-

source: formed on the basis of own research

It should be noted that the studied preparations had a positive effect on yield. The retained yield was 0,50–0,64 t/ha, which indicates the potential of the preparations in increasing yield compared to the control variant.

The mass of 1000 grains was determined in several variants, and in the control variant it was the smallest – 150,0 g, and in the other variants it ranged from 157,7 g to 159,2 g. This may indicate a difference in grain mass depending on the conditions or treatment. According to the research results, in the Vinnytsia region, soybean yield under the condition of double spraying with fungicides in the studied variants was higher compared to the control and amounted to 2,82–2,96 t/ha.

Conditionally net profit was from 25 844 UAH/ha in the control variant to 27 749 UAH/ha in the variant with the highest crop yield in the variant using *Aliette*, 80% w.p. + Abacus, CE c.e.), and the level of profitability in the conducted experiments the level of profitability was high in all variants, in the control, it was 67%. The highest level of profitability of 115% was recorded in the variant using the fungicides *Aliette,* 80% w.p. (2,0 kg/ha) and Abacus, CE c.e. (1,5 l/ha).

Conclusions. As a result of research conducted in the Vinnytsia region in 2023–2024, in the species structure of soybean diseases, according to the results of the research, Septoria (*Septoria glycines* Hemmi.*)* – 24% and *Alternaria tenuis* Nees. – *21%* were the dominant fungal diseases. Fusarium wilt *(Fusarium oxysporum* Schecht.*)* – 19%, Peronosporosis *(Peronospora manshurica* Sydow.*)* – 18% and *cercosporosis* (5%) were less common. The lowest level of damage was observed with powdery mildew (4%) and Ascochitosis *(Ascochyta sojaecola* Abramov.*) – 3%.* In addition, the share of bacterial diseases was 4%, and viral diseases – 2%.

It was noted that the technical efficiency of two-time spraying of soybean plants against diseases ranged from 65% to 82%. The best results were observed in the fight against downy mildew, and the highest efficiency was observed in the variants where the fungicides *Aliette,* 80% w. p. (2,0 kg/ha) and Abacus, CE c.e. (1,5 l/ha) were used in protecting plants from major diseases 78-82%.

According to the results of two-year studies, it was found that the average soybean yield in the experimental variants ranged from 3,32 t/ha in the control to 2,96 t/ha in the best yield variant with the use of fungicides *Aliette,* 80% w. p. (2,0 kg/ha) and Abacus, 12,5% for disease protection. The yield increase was 0,50–0,64 t/ha compared to the control conditions. Conditionally net profit ranged from 25,844 UAH/ha in the control variant to 27,749 UAH/ha in the variant with the highest crop yield (*Aliette,* 80% w. p. (2,0 kg/ha) + Abacus, CE c.e. (1,5 l/ha) and the profitability level was 115% in the variant using fungicides *Aliette,* 80% w. p. (2,0 kg/ha) and Abacus, CE c.e., which showed the best result.

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АНОТАЦІЯ
ЕФЕКТИВНІСТЬ ФУНГІЦИДНОГО ЗАХИСТУ СОЇ В УМОВАХ ЛІСОСТЕПУ ПРАВОБЕРЕЖНОГО

У даній статті висвітлено результати досліджень впливу дворазового застосування фунгіцидів на розвиток основних хвороб у посівах сої, а також на показники ефективності вирощування культури. За результатами фітопатологічного моніторингу в агроценозі сої у Вінницькій області, проведених у 2023–2024 роках, у ході досліджень встановлено видовий склад збудників хвороб сої. Домінуючими серед грибних хвороб виявилися септоріоз (24%) та альтернаріоз (21%). Менш поширеними були фузаріоз (19%), пероноспороз (18%) і церкоспороз (5%). Найнижчий рівень ураження спостерігався при борошнистій росі (4%) та аскохітозі (3%). Крім того, частка бактеріальних хвороб становила 4%, а вірусних – 2%.

Дослідженнями встановлено, що технічна ефективність за дворазового обприскування рослин сої проти основних хвороб становила 65% – 82%. Найвищу ефективність було зафіксовано у боротьбі з пероноспорозом. Серед застосованих препаратів найкращі результати продемонстрували фунгіциди Альєтт та Абакус, забезпечивши 78–82% захисту рослин від основних хвороб.

Середня врожайність сої у дослідних варіантах, становила від 3,32 т/га у контролі до 2,96 т/га у найкращому за врожайністю варіанті з використанням для захисту від хвороб фунгіцидів Альєтт, 80% з. п. та Абакус, 12,5% с. е. Прибавка врожаю становила 0,50–0,64 т/га порівняно з контролем. Умовно чистий прибуток, становив від 25844 грн/га у контрольному варіанті до 27749 грн/га у варіанті з найвищою урожайністю культури (Альєтт, 80% з.п. + Абакус, 12,5% с.е.), а рівень рентабельності становив 115% у варіанті з використанням фунгіцидів Альєтт, 80% з.п. і Абакус, 12,5% с.е., що показав найкращий результат.

Ключові слова: *сорт сої Титан, основні хвороби сої, сучасні фунгіциди, ураження, розвиток хвороб, ефективність, урожайність, рентабельність.*

Табл. 3. Рис. 1. Літ. 22.

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