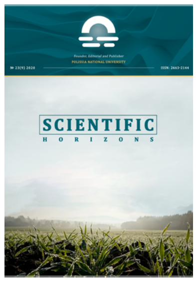
SCIENTIFIC HORIZONS
Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 26(2), 66-76



UDC 633.34: 632.952
DOI: 10.48077/scihor.26(2).2023.66-76

Formation of grain yield and quality indicators of soybeans under the influence of fungicidal protection

Mykola Grabovsky*
Doctor of Agricultural Sciences, Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
https://orcid.org/0000-0002-8494-7896

Olena Mostypan
PhD, Candidate
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
https://orcid.org/0000-0002-0743-7008

Yriy Fedoruk
Candidate of Agricultural Sciences, Associate Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
https://orcid.org/0000-0003-3921-7955

Leonid Kozak
Candidate of Agricultural Sciences, Associate Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
https://orcid.org/0000-0002-7770-9734

Mykhailo Ostrenko
Candidate of Agricultural Sciences, Associate Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
https://orcid.org/0000-0002-6772-3284

Article's History:
Received: 26.12.2022
Revised: 26.02.2023
Accepted: 14.03.2023

Suggested Citation:
Grabovskyi, M., Mostypan, O., Fedoruk, Y., Kozak, L., & Ostrenko, M. (2023). Formation of grain yield and quality indicators of soybeans under the influence of fungicidal protection. *Scientific Horizons*, 26(2), 66-76.

Abstract. Soybean diseases reduce the energy of seed germination, dilute crops, reduce the photosynthetic surface and productivity of cultivated plants, and worsen quality indicators. The purpose of the study was to determine the effect of fungicidal protection on the yield and quality of soybean grain. The following methods were used to achieve it: field, chemical (to determine the quality indicators of soybean grain), and statistical (to assess the reliability of data). The study was conducted in 2021-2022 in the conditions of TOV Savarske, Obukhiv district, Kyiv region. Soybean varieties Amadea and Aurelina and 10 variants of fungicidal protection were examined. It was identified that the increase in soybean grain yield when using fungicides is 0.41-0.72 t/ha, compared to the control. The highest yield in the experiment was obtained on the variants Celest top 312.5 FS, TH (1 l/t) + Abacus (2 l/ha) and Standak Top

*Corresponding author

(2 l/t) + Abacus (2 l/ha) – 3.31 and 3.37 t/ha and 3.06 and 3.13 t/ha, respectively, in the varieties Amadea and Aurelina. There was no effect of the fungicides under study on the moisture content of soybean grains and the fat content of soybean seeds. There is an increase in protein content by 0.3-1.8% in variants with the use of fungicidal protection, compared to the control. The highest fat and protein content was obtained on the variant Standak Top (2 l/t) + Abacus (2 l/ha) and Celest top 312.5 FS, TH (1 l/t) + Abacus (2 l/ha) – 21.9 and 21.7% and 38.5 and 42.4%, respectively, in the varieties Amadea and Aurelina. The results of the conducted studies can be used in production conditions to improve the protection of soybean crops from diseases and increase the yield and quality of grain of this crop

Keywords: soy; fungicides; productivity; grain quality; pre-sowing seed treatment

INTRODUCTION

Soybeans are one of the most profitable crops in Ukraine, and its global acreage increases every year. Therewith, the yield of this crop is unstable and changes under the influence of many factors, one of which is the infection of soybean seedlings and the leaf apparatus by fungal diseases. The use of plant protection products is required to level or reduce the impact of fungal diseases on soybean plants, one of the most effective of which are fungicides. Due to the emergence of new fungicidal preparations, it becomes expedient to examine their effect on the yield and quality of soybean grain.

The studies (Baysal-Gurel, 2018; Kots, 2021) note that high economic and food losses from damage to soybean plants by phytopathogens cause the need for crop protection. Modern fungicides are effective compounds that act on specific biochemical processes of pathogen growth and development and stimulate the protective mechanisms of cultivated plants. However, there are problems using synthetic fungicides, which include hazards to human health, damage to aquatic ecosystems, reduction of the number of beneficial microorganisms in the soil, and even damage to the ozone layer. According to Christopher (2010), frequent and indiscriminate use of fungicides can promote the development of fungicide resistance.

The study by Bandara *et al*. (2020) identified a substantial and positive association between soybean yield and fungicide use in most years of the study. According to the data obtained by Kandel *et al*. (2021), mixtures of fungicides from several groups of active ingredients (two or three ingredients) increase soybean yield by 3.0% compared to the control. Therewith, the average yield increase over the years of observation (2005-2018) is 2.7%. As noted in the study by Bluck (2015), the absence of fungicides in the soybean cultivation system reduced grain yields in 5 out of 13 years of the experiment (2000-2013) by 0.21-0.79 t/ha, and their use increased yields by an average of 0.47 t/ha.

According to the results of the study conducted with the fungicides Triazole (tebuconazole) and Strobilurine (pyraclostrobin) by Swoboda (2009), it was identified that their separate and combined use in soybean crops did not result in a substantial effect on grain yield. In this study, fungicides were used in the absence of fungal diseases and had no non-fungicidal physiological effect on soybean plants.

Hanna (2008) and Mourtzinis (2017) think that the phase of crop development in which the fungicide is used substantially affects its effectiveness and ability to suppress diseases. In addition, there is a decrease in the effectiveness of fungicides due to unfavourable environmental conditions and their use on soybean varieties that are resistant to diseases. According to Bestor (2011) and Chanda (2014), there is no clear understanding of the correct period of application of fungicides. In many soybean-producing countries, the use of fungicides for disease control is based on a fixed stage of crop growth, usually between R3 and R5. This phenology-based criterion is widely accepted because of its ease of implementation, as it does not require disease detection or diagnosis (Carmona, 2015).

According to Pavlishche *et al*. (2017), soybean seed treatment had a negative impact on nodulation processes, nodule nitrogen-fixing activity, photosynthetic intensity, and leaf transpiration. Therewith, the degree of manifestation of the effect depended on the drug and the method of treatment. Early, two weeks before sowing, seed treatment had less effect on the symbiotic apparatus compared to etching together with inoculation on the day of sowing, but it had a stronger effect on the physiological state of the plant itself, in particular, on photosynthesis and transpiration. Rybachenko (2021) studies showed that the fungicides Fever and Standak Top slightly inhibit the nodulation activity of rhizobia in the phase of 2 true leaves of soybean. Therewith, in the phase of 3 true leaves and budding, these drugs activate the processes of nodule formation and fixation of molecular nitrogen. Therewith, the results of field experiments by Omelchuk (2019) show that the use of Acanto Plus fungicide contributed to a more complete realisation of the productive capacity of soy-rhizobial symbiosis of soybeans and an increase in seed weight by 21% compared to the control.

Mostovyak & Kravchenko (2018) note that in the conditions of the Forest-Steppe of Ukraine, the use of fungicides Acanto Plus 28 KS (1.0 l/ha), Amistar Extra 280 SC (0.75 l/ha), Bumper Super 490 SE (1.5 l/ha), Impact K, KC (0.8 L/ha), Coronet 300 SC KS (0.8 L/ha) in crops soy leads to intensive passage of growth and photosynthetic processes in plants, accompanied by an increase of 20-48% of the leaf surface area, 58-79% of the amount of chlorophylls A and B in the leaves, and 7-9% of the net productivity of photosynthesis of crops.

According to Kandel *et al*. (2016) and Bradley (2008), fungicides can be used for preventive purposes to increase soybean yields, but their use was profitable in about 14% of cases based on the average market price of soybeans in 2008-2014. According to Orlowski (2016), the use of fungicides is profitable even in the absence of diseases. In addition, as noted by Bergman *et al*. (2020), it is necessary to adhere to the principles of Integrated disease control and use fungicides only if they are known or highly likely to occur. A similar opinion is shared by Swoboda *et al*. (2009), which indicates that environmental conditions and disease assessment should be used as a reference for foliar application of fungicides on soybeans.

A review of literature sources indicates a lack of consensus on the type of fungicides, the period of their application, and their impact on the growth processes, productivity, and quality indicators of soybeans. Therefore, the purpose of these studies was to identify the features of the formation of productivity and quality of soybean grain depending on fungicidal protection.

MATERIALS AND METHODS

The study was conducted in 2021-2022 in the conditions of TOV Savarske, Obukhiv district, Kyiv region. The scheme of the experiment is shown in Table 1.

***Table 1**. Experiment scheme*

Soybean varieties (factor A)	Fungicides (Factor B)
Amadea	Control
	Maxim Advance (1.25 l/t)
	Vibrance (1 l/t)
	Celest top (1 l/t)
	Standak Top (2 l/t)
Aurelina	Abacus (2 l/ha)
	Maxim Advance (1.25 l/t) + Abacus (2 l/ha)
	Vibrance (1 l/t) + Abacus (2 l/ha)
	Celest top (1 l/t) + Abacus (2 l/ha)
	Standak Top (2 l/t) + Abacus (2 l/ha)

***Source:** compiled by the authors*

Seed treatment with fungicides was conducted before sowing and spraying of crops during the growing season (before the budding phase) by applying a working solution (250 l/ha) in experimental plots. On the control variants, seeds were treated, and crops were sprayed with water at the rate of 250 l/ha during the period when fungicides were applied.

The total area of the basic plot is 144 m^2, accounting – 120 m^2. The experiment is repeated three times. Soil of experimental plots – typical medium-loamy loamy chernozem. The content of humus is 2.56%, easily hydrolysed nitrogen – 145 mg/kg, mobile phosphorus – 167 mg/kg, exchange potassium – 178 mg/kg. The degree of soil pH acidity – 6.1.

In 2021, the weather conditions were favourable for the growth, development, and formation of soybean productivity. In some months (May and July), there was 63 and 78% more precipitation compared to the long-term average. In 2022, air and soil droughts were observed in May and June, and there was an excess of precipitation only in September (112.6 mm), which did not affect soybean productivity. That is, this year was unfavourable for soybeans in terms of climate indicators.

Yield accounting was conducted separately by the method of continuous threshing of each plot, followed by recalculation for 100% purity and standard humidity. The protein content was determined by the Kjeldahl method, and the fat content was determined by the extraction of the suspension with ethyl ether in the Soxlet apparatus according to DSTU 4964:2008 (2010). The analysis of the obtained data was conducted using the methods of dispersion and variation analysis using Microsoft Excel and Statistics 12.0 computer programmes.

RESULTS AND DISCUSSION

Based on the results of the conducted studies, it was identified that the yield of the soybean varieties under study depended both on the hydrothermal conditions of the year of research and the use of fungicides (Table 2).

Table 2. Effect of fungicides on soybean grain yield, t/ha

Experiment variant	2021	2022	Average	Increase compared with control
Amadea				
Control	2.98	2.03	2.50	–
Maxim Advance (1.25 l/t)	3.50	2.34	2.92	0.42
Vibrance (1 l/t)	3.52	2.35	2.94	0.44
Celest top (1 l/t)	3.78	2.58	3.18	0.68
Standak Top (2 l/t)	3.84	2.64	3.24	0.74
Abacus (2 l/ha)	3.42	2.28	2.85	0.35
Maxim Advance (1.25 l/t) + Abacus (2 l/ha)	3.63	2.51	3.07	0.57
Vibrance (1 l/t) + Abacus (2 l/ha)	3.66	2.52	3.09	0.59
Celest top (1 l/t) + Abacus (2 l/ha)	3.93	2.69	3.31	0.81
Standak Top (2 l/t) + Abacus (2 l/ha)	4.00	2.74	3.37	0.87
Aurelina				
Control	3.03	1.84	2.43	–
Maxim Advance (1.25 l/t)	3.27	2.20	2.73	0.30
Vibrance (1 l/t)	3.30	2.21	2.75	0.32
Celest top (1 l/t)	3.50	2.41	2.95	0.52
Standak Top (2 l/t)	3.52	2.46	2.99	0.55
Abacus (2 l/ha)	3.20	2.18	2.69	0.26
Maxim Advance (1.25 l/t) + Abacus (2 l/ha)	3.42	2.36	2.89	0.46
Vibrance (1 l/t) + Abacus (2 l/ha)	3.44	2.38	2.91	0.48
Celest top (1 l/t) + Abacus (2 l/ha)	3.59	2.54	3.06	0.63
Standak Top (2 l/t) + Abacus (2 l/ha)	3.67	2.60	3.13	0.70
HIP_{05}	0.11	0.09	0.12	

Source: *compiled by the authors*

The weather conditions of 2022 were unfavourable for soybeans, which affected the growth and development of plants and the level of crop yield in general. Depending on the factors under study, it ranged from 1.84 (Aurelina variety, control) to 2.74 t/ha (Amadea variety, Standak Top (2 l/t) + Abacus (2 l/ha)). In 2021, the hydrothermal regime during the growing season of soybeans contributed to the maximum realisation of the genetic potential of soybean varieties, which allowed obtaining grain yields from 2.98 (Amadea variety, control) to 4.00 t/ha (Amadea variety, Standak Top (2 l/t) + Abacus (2 l/ha)). The decrease in yield in 2022 was 28.2-33.4% compared to the previous year.

The use of fungicides had a positive effect on increasing the yield of soybeans of both varieties during the years of research. Thus, under the influence of this technological measure, the yield increase was 0.42-0.87 t/ha for the Amadea variety and 0.30-0.70 t/ha for the Aurelina variety, compared to the control. The difference between the fungicide protection options was greater in 2022. On average, for two years, the most effective option was pre-sowing seed treatment with Standak Top (2 l/t) and spraying plants during the growing season with Abacus (2 l/ha). The grain yield was 3.37 and 3.13 t/ha, respectively, in the varieties Amadea and Aurelina. Notably, in both varieties there was no substantial difference between this option and the use of Celest top (1 l/t) + Abacus (2 l/ha), which was within the error range of the experiment (HIP05 in 2021 – 0.11, in 2022 – 0.09 t/ha). There is also no substantial difference between the use of Maxim Advance (1.25 l/t) + Abacus (2 l/ha) and Vaibrans (1 l/t) + Abacus (2 l/ha), Maxim Advance (1.25 l/t) and Vaibrans (1 l/t), and Celest top (1 l/t) and Standak Top (2 l/t). This is due to the similar mechanism of action of the examined drugs, especially in the initial period, on pathogens.

In general, options with the combined use of pre-sowing seed treatment and the introduction of fungicides on vegetative soybean plants were more effective. Therewith, in areas with pre-sowing treatment of seeds with Maxim Advance (1.25 l/t), the grain yield was 0.4-0.7 t/ha higher than with post-emergence application of Abacus (2 l/ha). On average over the years of the study, the grain yield of the Amadea variety was 2.7-7.7% higher than the Aurelina variety. The yield of the Amadea variety was in the range of 2.03-3.70 t/ha and the Aurelina variety – 1.84-3.43 t/ha (Fig. 1).

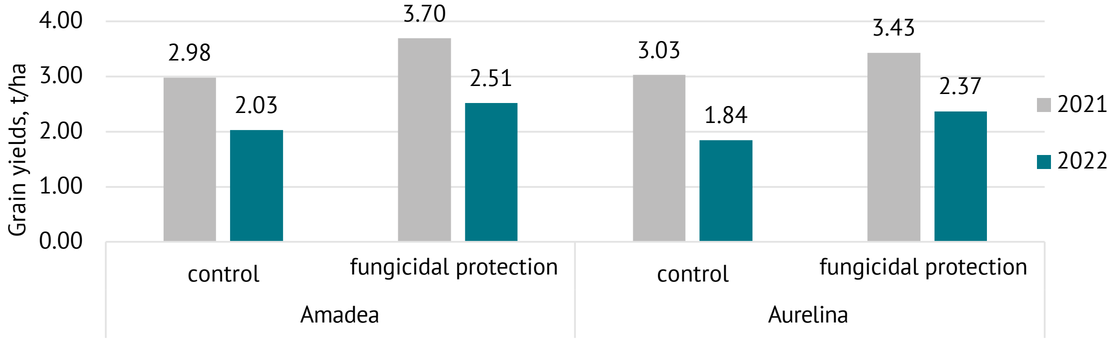


***Figure 1**. Yield of soybean varieties depending on the application of fungicidal protection, t/ha*

***Source:** compiled by the authors*

The use of fungicides provides an increase in the yield of soybean grain in the range of 0.41-0.72 t/ha, compared to the control. The above-mentioned increases in the yield level indicate a high efficiency of using fungicides. Based on the results of the variance analysis of data for the years of research, the share of involvement of the factors under study and their interaction in the formation of grain yield of soybean varieties Amadea and Aurelina was established (Table 3).

***Table 3**. Variance analysis of soybean yield in 2021-2022*

Factor	MS	p	Involvement part, %	Substantiality
Variety (A)	3.288	<0.001	17.1	*
Fungicides (B)	2.404	<0.001	12.5	*
Year (Y)	12.519	<0.001	65.1	*
A x B	0.808	<0.001	4.3	*
B x Y	0.154	<0.001	0.8	*
Other interactions	<0,01	>0.05	0.2	ns

***Note:** p≤0.05; ns – not substantial, p>0.05*

***Source:** compiled by the authors*

Weather conditions (year) had the greatest impact (65.1%) on the formation of soybean yields. The genotypic effect (variety) was at the level of 17.1% and the share of fungicides in the formation of soybean yield was 12.5%. The interaction "variety – fungicidal protection" was substantial (4.3%), and the interaction "fungicides – weather conditions (year)" was insubstantial. A direct high relationship was established between the yield and precipitation for the soybean growing season (r=0.85 in 2021 and r=0.92 in 2022) and the sum of effective temperatures for the growing season (r=0.88 in 2021, r=0.96 in 2022).

According to Podpryatov (2014), the moisture content of soybean grain during harvesting should be 14-16%, because at values of 11-12%, beans crack, cracks form in the seeds, through which pathogens enter, leading to substantial grain losses. When the grain moisture content is over 20%, the seeds are deformed, the embryo is damaged and cannot be completely grounded from the beans.

There was no effect of the fungicides under study on the moisture content of soybean grain, this indicator depended on the weather conditions of the year and varietal characteristics (Table 4). The highest indicators of grain moisture were in 2022 – 8.9-9.6% and 8.4-9.2% and lower in 2021 – 7.8-8.6% and 7.8-8.4%, respectively, in the varieties Amadea and Aurelina. The Amadea Variety had a 0.2-0.7% higher grain moisture content compared to the Aurelina variety.

***Table 4**. Effect of fungicides on grain moisture of soybean varieties, %*

Experiment variant	**2021**	**2022**	**Average**
	Amadea		
Control	8.1	9.4	8.8
Maxim Advance (1.25 l/t)	8.4	9.0	8.7
Vibrance (1 l/t)	8.3	8.9	8.6
Celest top (1 l/t)	7.9	9.1	8.5
Standak Top (2 l/t)	8.2	9.4	8.8

Table 4, Continued

Experiment variant	2021	2022	Average
	Amadea		
Abacus (2 l/ha)	7.8	9.6	8.7
Maxim Advance (1.25 l/t) + Abacus (2 l/ha)	8.0	9.3	8.7
Vibrance (1 l/t) + Abacus (2 l/ha)	8.6	9.3	9.0
Celest top (1 l/t) + Abacus (2 l/ha)	8.5	9.0	8.8
Standak Top (2 l/t) + Abacus (2 l/ha)	7.9	9.5	8.7
	Aurelina		
Control	8.3	8.8	8.6
Maxim Advance (1.25 l/t)	7.8	8.7	8.3
Vibrance (1 l/t)	8.6	9.2	8.9
Celest top (1 l/t)	7.9	8.7	8.3
Standak Top (2 l/t)	8.0	8.9	8.5
Abacus (2 l/ha)	7.8	9.0	8.4
Maxim Advance (1.25 l/t) + Abacus (2 l/ha)	8.4	8.5	8.5
Vibrance (1 l/t) + Abacus (2 l/ha)	7.9	8.6	8.3
Celest top (1 l/t) + Abacus (2 l/ha)	7.8	8.7	8.3
Standak Top (2 l/t) + Abacus (2 l/ha)	7.8	8.4	8.1
HIP_{05}	0.1	0.2	0.2

Source: *compiled by the authors*

The fat content of soybean seeds depended on the genotypic characteristics of the studied varieties. There was no substantial effect of fungicides on fat accumulation in soybean grain, there was only a tendency to increase it by 0.1-0.4% in the experimental areas with their use, compared to the control. In the Amadea variety, on average for two years, this indicator was higher than in the Aurelina variety by 0.1-0.4% and varied in the range of 21.3-21.7%, and in the Aurelina variety, it was 21.0-21.6% (Fig. 2).

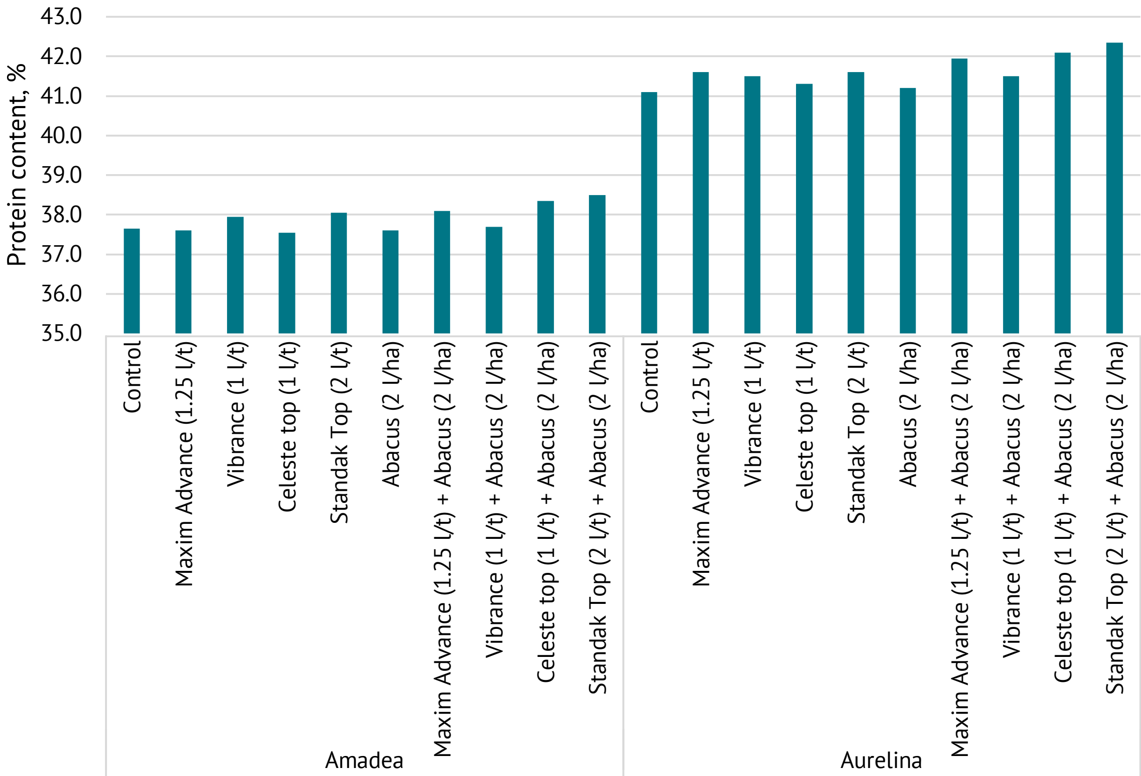


***Figure 2**. Soybean grain fat content (average for 2021-2022), %*

Source: *compiled by the authors*

The protein content in soybean grains varied between 37.5-38.5% in the Amadea variety and 40.6-42.4% in the Aurelina variety (Fig. 3). In the Amadea variety, the protein content in the grain was 3.1-3.9% lower compared to the Aurelina variety. In the variants using fungicidal protection, the protein content increased in the varieties Amadea and Aurelina by 0.3-1.0% and 0.7-1.8%, compared to the control. The highest protein content in both varieties was obtained using Celest top (1 l/t) + Abacus (2 l/ha) – 38.4 and 42.1 % and Standak Top (2 l/t) + Abacus (2 l/ha) – 38.5 and 42.4%, respectively, in the varieties Amadea and Aurelina.

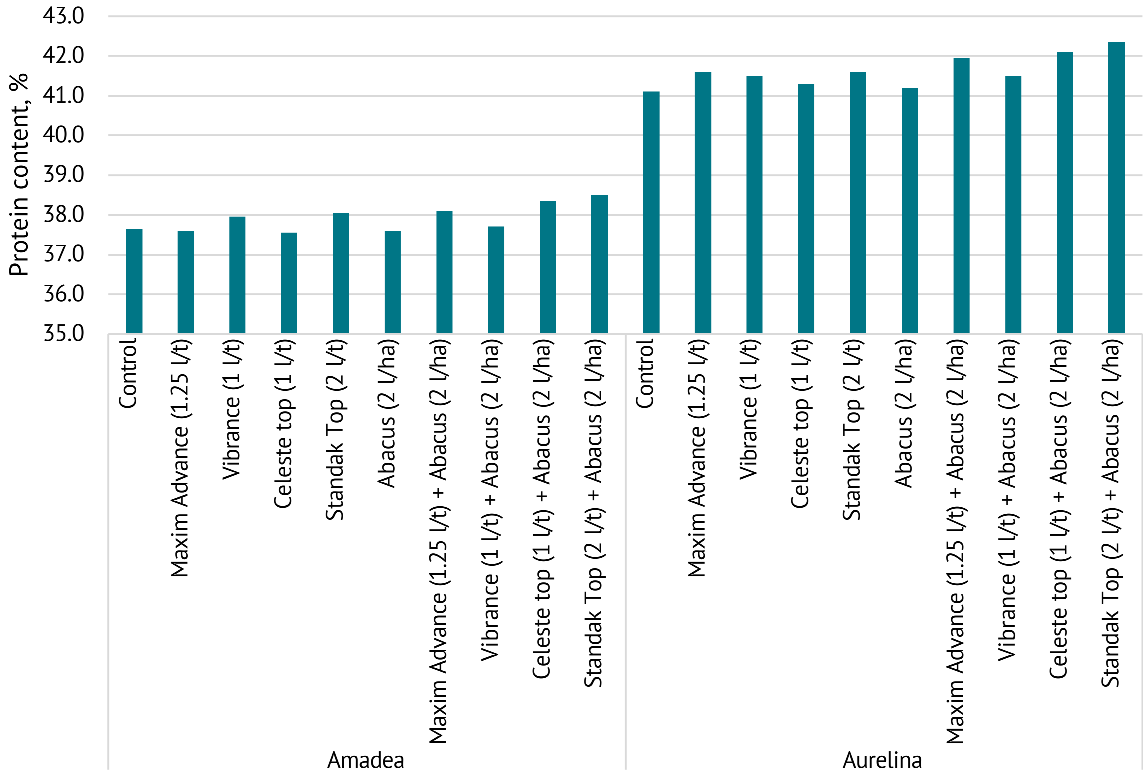


***Figure 3**. Protein content in soybean grains (average for 2021-2022), %*
***Source:** compiled by the authors*

Consequently, an increase in soybean grain yield was identified in the range from 0.41 to 0.72 t/ha and protein content from 0.3 to 1.8%, on variants using fungicides, compared with the control. The effect of the fungicides under study on the moisture content of soybean grains and the fat content of soybean seeds was not established. The highest yield of soybeans in the experiment, in the varieties Amadea and Aurelina, was obtained on the variants Celest top 312.5 FS, TH (1 l/t) + Abacus (2 l/ha) and Standak Top (2 l/t) + Abacus (2 l/ha) – 3.31 and 3.37 t/ha and 3.06 and 3.13 t/ha.

According to the results of the conducted studies, a substantial increase in the yield of soybean grain on variants using fungicides was established. This is consistent with the data of other researchers. Thus, Kosylovych & Golyachuk (2020) identified that the highest soybean yield was obtained when applying fungicides Aliette, 80% WP (1.5 kg/ha), Propulse, 25% SE (0.8 l/ha) – 37.5 cwt/ha, which was 11.0 cwt/ha in addition to the control. Shendryk (2018), in the conditions of the Bila Tserkiva experimental breeding station, the high efficiency of the fungicide Propulse 250 SE against a complex of soybean diseases and an increase in soybean yield by 1.0-1.5 t/ha, compared to the control, was established. As noted by Shcherbachuk (2015), double application of fungicides Coronet (0.6 l/ha) and Abacus (1.5 l/ha) provides the highest yield of soybeans – 2.70 t/ha and the highest protein content – 37.8%.

Kolisnyk (2020) identifyed that pre-sowing seed treatment with Rhizoactive + Maxim XL 035 FS in combination with Abacus fungicide contributed to an increase in soybean seed yield to 2.65 t/ha. According to Ng (2018), fungicide treatment of soybean seeds and crops increased yields in 4 out of 12 years of testing compared to the control. The use of a separate fungicide, insecticide, or a mixture of both did not improve yields in the absence of harmful entomofauna or phytopathogens at threshold levels on soybean plants. In the studies by Mostovyak (2019), soybean grain yields increased by 11-15% when using fungicides. Other researchers also note the positive effect of fungicides on soybean productivity (Kolisnyk, 2020; Grassini, 2015; Vann, 2021). Some researchers (Swoboda & Pedersen, 2009; Ng, 2018) emphasise the importance of regulated use of fungicides in soybean cultivation. As noted, (Bergman, 2020; Junqueira, 2021; Bestor, 2011) fungicides should only be used if certain diseases are present or highly likely to occur in soybean crops.

According To Rotundo (2009), high air temperatures and low precipitation during seed formation and reproductive growth lead to higher protein concentrations in soybean seeds. The increase in protein synthesis depends on the time and degree of environmental stress. This increase in protein content may be the reason for the low correlation of protein content with grain yield.

According to the results obtained, the protein content depended on varietal characteristics and did not change substantially over the years of the study. The authors did not calculate the correlation between grain yield and protein content. An increase in protein content of 0.3-1.8% was identified in variants using fungicidal protection, compared with the control. This is consistent with the data obtained by Hryhor'eva (2020) and Hadzovsky (2020).

According to the data obtained, the use of fungicides did not cause substantial differences in changes in the fat content in soybean grains, which is confirmed by other researchers (Kosylovych, 2020; Procházka, 2017; Ghahari, 2017). However, based on the results obtained by Siddiqui (2006) with an increase in the dose of fungicides, the protein and fat content in soybean grains decreased. The insufficient number of studies to examine the effect of fungicides on the quality indicators of soybean grain is notable. That is, the question of the effect of fungicides on protein and fat content requires further study.

CONCLUSIONS

Based on the results of the conducted studies, the influence of pre-sowing seed treatment and post-emergence use of fungicides on the productivity of soybean varieties was established. On average, the increase in soybean grain yield is 0.41-0.72 t/ha, compared to the control. The highest yield in the experiment was obtained on the following variants: Celest top 312.5 FS, TH (1 l/t) + Abacus (2 l/ha) and Standak Top (2 l/t) + Abacus (2 l/ha) – 3.31 and 3.37 t/ha and 3.06 and 3.13 t/ha, respectively, in the varieties Amadea and Aurelina. The grain yield in the Amadea variety was 2.7-7.7% higher than in the Aurelina variety.

Soybean productivity depended on the hydrothermal conditions of the year. Thus, in the best in terms of precipitation year of 2021, the yield of Amadea and Aurelina varieties, depending on the fungicidal protection, was 2.98-4.00 and 3.03-3.67 t/ha, respectively. And in the unfavourable climatic year 2022, the yield was 2.03-2.74 and 1.84-2.60 t/ha, respectively. The decrease in yield in 2022 was 28.2-33.4% compared to the previous year.

The effect of the fungicides under study on the moisture content of soybean grains and the fat content of soybean seeds was not established. An increase in protein content by 0.3-1.8% was identified in variants using fungicidal protection, compared with the control. The highest fat and protein content is obtained when using fungicides Standak Top (2 l/t) + Abacus (2 l/ha) – 21.9 and 21.7% and 38.5 and 42.4%, respectively, in the varieties Amadea and Aurelin. The high efficiency of the examined fungicides is explained by their effect on pathogens in the initial period of soybean plant ontogenesis and the development of fungal diseases during the growing season. Therewith, it requires further research to determine the effectiveness of fungicides as preventive drugs, justify the economic feasibility of their use, and their impact on the quality indicators of soybean grain.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the “Donau Soja Ukraine” association and personally to Mykola Bykov for their assistance in organising and conducting the study.

CONFLICT OF INTEREST

None.

REFERENCES

[1] Allen, T, Hollier, C, & Sikora, E. (2014). A continuing saga: Soybean rust in the continental United States, 2004 to 2013. *Outlooks on Pest Management*, 25(2), 167-174. doi: 10.1564/v25_apr_05.

[2] Bandara, A.Y., Weerasooriya, D.K., Conley, S.P., Bradley, C.A., Allen, T.W., & Esker, P.D. (2020). Modeling the relationship between estimated fungicide use and disease-associated yield losses of soybean in the United States I: Foliar fungicides vs foliar diseases. *PLoS One*, 15(6), article number e0234390. doi: 10.1371/journal.pone.0234390.

[3] Baysal-Gurel, F., & Kabir, N. (2018). Comparative performance of fungicides and biocontrol products in suppression of Rhizoctonia root rot in viburnum. *Journal of Plant Pathology & Microbiology*, 9(9), article number 451. doi: 10.4172/2157-7471.1000451.

[4] Bergman, K., Ciampitti, I., Sexton, P., & Kovács, P. (2020). Fungicide, insecticide, and foliar fertilizer effect on soybean yield, seed composition, and canopy retention. *Agrosystems, Geosciences & Environment*, 4(2), 2639-6696. doi: 10.1002/agg2.20116.

[5] Bestor, N. (2011). *The effect of fungicides on soybean in Iowa applied alone or in combination with insecticides at two application growth stages on disease severity and yield*. IA: Iowa State University Ames. doi: 10.31274/etd-180810-2555.

[6] Bluck, G.M., Lindsey, L.E., Dorrance, A.E., & Metzger, J.D., (2015). Soybean yield response to rhizobia inoculant, gypsum, manganese fertilizer, insecticide, and fungicide. *Agronomy Journal*, 107(5), 1757-1765. doi: 10.2134/agronj15.0094.
[7] Bradley, C.A. (2008). Effect of fungicide seed treatments on stand establishment, seedling disease, and yield of soybean in North Dakota. *Plant Diseases*, 92(1), 120-125. doi: 10.1094/PDIS-92-1-0120.
[8] Carmona, M., Sautua, F., Perelman, S., Gally, M., & Reis, E.M. (2015). Development and validation of a fungicide scoring system for management of late season soybean diseases in Argentina. *Crop Protection*, 70, 83-91. doi: 10.1016/j.cropro.2015.01.019.
[9] Chanda, A.K., Ward, N.A., Robertson, C.L., Chen, Z.Y., & Schneider, R.W. (2014). Development of a quantitative polymerase chain reaction detection protocol for Cercospora kikuchii in soybean leaves and its use for documenting latent infection as affected by fungicide applications. *Phytopathology*, 104(10), 1118-1124. doi: 10.1094/PHYTO-07-13-0200-R.
[10] Christopher, D.J., Raj, T.S., Rani, S.U., & Udhayakumar, R. (2010). Role of defense enzymes activity in tomato as induced by *Trichoderma virens* against Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lycopersici*. *Journal of Biopesticodes*, 3, 158-162
[11] DSTU 4964:2008. (2010). *Soy. Technical conditions*. Retrieved from https://docplayer.net/31317538-Nacionalniy-standart-ukrayini-soya.html.
[12] Ghahari, S., Alinezhad, H., Nematzadeh, G.A., Tajbakhsh, M., & Baharfar R. (2017). Chemical composition, antioxidant and biological activities of the essential oil and extract of the seeds of glycine max (soybean) from North Iran. *Current Microbiology*, 74, 522-531. doi: 10.1007/s00284-016-1188-4.
[13] Grassini, P., Torrion, J.A., Yang, H.S., Rees, J., Andersen, D., Cassman, K.G., & Specht, J.E. (2015). Soybean yield gaps and water productivity in the western U.S. Corn Belt. *Field Crops Research*, 179, 150-163. doi: 10.1016/j.fcr.2015.04.015.
[14] Hadzovskyi, H.L., Novytska, N.V., & Martynov O.M. (2020). Yield and quality of soybeans grain under influence of inoculation and foliar top dressing. T*aurian Scientific Bulletin*, 111, 44-48. doi: 10.32851/2226-0099.2020.111.5.
[15] Hanna, S.O., Conley, S.P., Shaner, G.E., & Santini, J.B. (2008). Fungicide application timing and row spacing effect on soybean canopy penetration and grain yield. *Agronomy Journal*, 100, 1488-1492. doi: 10.2134/agronj2007.0135.
[16] Hryhor'eva, O.M., Cheryachukin, M.I., & Almayeva, T.M. (2020). Technology of growing soybean with elements of biology in the conditions of risky agriculture of the right bank steppe of Ukraine. *Cereal Crops*, 4(1), 87-95. doi: 10.31867/2523-4544/0110.
[17] Junqueira, V.B., Müller, C., Rodrigues, A.A., Amaral, T.S., Batista, P.F., Silva, A.A., & Costa, A.C. (2021). Do fungicides affect the physiology, reproductive development and productivity of healthy soybean plants? *Pesticide Biochemistry and Physiology*, 172, article number 104754. doi: 10.1016/j.pestbp.2020.104754.
[18] Kandel, Y.R., *et al*. (2021). Meta-Analysis of soybean yield response to foliar fungicides evaluated from 2005 to 2018 in the United States and Canada. *Plant Disease*, 105(5), 1382-1389. doi: 10.1094/PDIS-07-20-1578-RE.
[19] Kandel, Y.R., Mueller, D.S., Bestor, N.R.C., Bradley, C.A., Ames, K.A., Giesler, L.J., & Wise, K.A. (2016). Analyses of yield and economic response from foliar fungicide and insecticide applications to soybean in the North Central United States. *Plant Health Progress*, 17, 232-238. doi: 10.1094/PHP-RS-16-0038.
[20] Kolisnyk, S.I., Kobak, S.Ya., & Panasiuk, O.Ya., (2020). Effectiveness of soybean disease protection systems in short-rotational crop rotations of the Pravoberezhnyi Forest Steppe. *Agronom*, 84, 133-140.
[21] Kosylovych, G., & Golyachuk, Yu. (2020). Protection of soybeans from diseases. *Bulletin of LNAU. Series: Agronomy*, 24, 163-167.
[22] Kots, S.Ya., & Pavlishche, A.V. (2021). The use of fungicides in integrated soybeans protection systems and their impact on the physiological and biochemical processes in plants under inoculation. *Physiology of Plants and Genetics*, 53(1), 3-28. doi: 10.15407/frg2021.01.003.
[23] Mostovyak, I.I., & Kravchenko, O.V. (2019). Productivity of soybean crops using different types of fungicides and inoculants. *Quarantine and Plant Protection*, (3-4), 1-3. doi: 10.36495/2312-0614.2019.3-4.1-3.
[24] Mostovyak, I.I., & Kravchenko, O.V., (2018). Formation of photosynthetic productivity of soybean crops using different types of fungicides and inoculants in the Right Bank Forest Steppe of Ukraine. *Bulletin of the Uman National University of Horticulture*, 2, 21-24. doi: 10.31395/2310-0478-2018-21-21-24.
[25] Mourtzinis, S., Marburger, D., Gaska, J., Diallo, T., Lauer, J.G., & Conley, S. (2017). Corn, soybean, and wheat yield response to crop rotation, nitrogen rates, and foliar fungicide application. *Crop Science*, 57, 983-992. doi: 10.2135/cropsci2016.10.0876.
[26] Ng, S.J., Lindsey, L.E., Michel, A.P., & Dorrance, A.E. (2018). Effect of mid-season foliar fungicide and foliar insecticide applied alone and in combination on soybean yield. *Crop, Forage and Turfgrass Management*, 4, 1-6. doi: 10.2134/cftm2017.09.0067.

[27] Omelchuk, S.V., & Yakymchuk, R.A. (2019). Efficacy of soybean-rhizobia symbiosis under the influence of fungicide acanto plus. *Physiology of Plants and Genetics*, 51(5), 447-454. doi: 10.15407/frg2019.05.447.
[28] Orlowski, J.M., Haverkamp, B.J., Laurenz, R.G., Marburger, D.A., Wilson, E.W., Casteel, Sh.N., Conley, Sh.P., Naeve, S.L., Nafziger, E.D., Roozeboom, K.L., Ross, W.J., Thelen, K.D., & Lee, Ch.D. (2016). High-input management systems effect on soybean seed yield, yield components, and economic break-even probabilities. *Crop Science*, 56, 1988-2004. doi: 10.2135/cropsci2015.10.0620.
[29] Pavlishche, A.V., Kiriziy, D.A., & Kots, S.Ya. (2017). Reaction of soybean symbiotic systems to the action of fungicides under different treatment methods. *Physiology of Plants and Genetics*, 49(3), 237-247. doi: 10.15407/frg2017.03.237.
[30] Podpryatov, G.I., Rozhko, V.I., & Skaletska, L.F. (2014). *Technology of storage and processing of plant products: A textbook*. Kyiv: Agrarian education.
[31] Procházka, P., Štranc, P., Pazderů, K., Štranc, J., & Vostřel, J. (2017). Effects of biologically active substances used in soybean seed treatment on oil, protein and fibre content of harvested seeds. *Plant Soil and Environment*, 63(12), 564-568. doi: 10.17221/702/2017-PSE.
[32] Rotundo, J.L., & Westgate, M.E. (2009). Meta-analysis of environmental effects on soybean seed composition. *Field Crops Research*, 110(2), 147-156. doi: 10.1016/j.fcr.2008.07.012.
[33] Rybachenko, L., Kots, S., Pavlishche, A., Rybachenko, O., & Khomenko, Yu. (2021). Features of the functioning of soy-rhizobial systems under the influence of fungicides and the complex drug Stimpo. *Physiology of Plants and Genetics*, 53(4), 307-319. doi: 10.15407/frg2021.04.307.
[34] Shcherbachuk, V.M. (2015). Formation of productivity of soybean crops depending on the system of protection against diseases. *Bulletin of Agrarian Science of the Black Sea Region*, 2, 119-123. doi: 10.31521/2313-092X.
[35] Shendryk, K.M. (2018). Modern fungicide Propuls 250 SE to protect soybeans against a complex of phytopathogens. *Scientific Works of the Institute of Bioenergy Crops and Sugar Beet*, 26, 48-55. doi: 10.47414/np.26.2018.211194.
[36] Siddiqui, Z.S., & Ahmed, S. (2006). Combined effects of pesticide on growth and nutritive composition of soybean plants. *Pakistan Journal of Botany*, 38, 721-33.
[37] Swoboda, C., & Pedersen, P. (2009). Effect of fungicide on soybean growth and yield. *Agronomy Journal*, 101, 352-356. doi: 10.2134/agronj2008.0150.
[38] Vann, R.A., Drake-Stowe, K., Buol, G.S., & Dunphy, E.J. (2021). Production practices that maximize soybean yield: what we have learned from the North Carolina soybean yield contest. *Agronomy Journal*, 113, 3399-3417. doi: 10.1002/agj2.20728.

Формування урожайності зерна та якісних показників сої під впливом фунгіцидного захисту

Микола Борисович Грабовський

Доктор сільськогосподарських наук, професор
Білоцерківський національний аграрний університет
09117, пл. Соборна, 8/1, м. Біла Церква, Україна
https://orcid.org/0000-0002-8494-7896

Олена Валеріївна Мостипан

Здобувач ступеня доктора філософії
Білоцерківський національний аграрний університет
09117, пл. Соборна, 8/1, м. Біла Церква, Україна
https://orcid.org/0000-0002-0743-7008

Юрій Васильович Федорук

Кандидат сільськогосподарських наук, доцент
Білоцерківський національний аграрний університет
09117, пл. Соборна, 8/1, м. Біла Церква, Україна
https://orcid.org/0000-0003-3921-7955

Леонід Андрійович Козак

Кандидат сільськогосподарських наук, доцент
Білоцерківський національний аграрний університет
09117, пл. Соборна, 8/1, м. Біла Церква, Україна
https://orcid.org/0000-0002-7770-9734

Михайло Володимирович Остренко

Кандидат сільськогосподарських наук, доцент
Білоцерківський національний аграрний університет
09117, пл. Соборна, 8/1, м. Біла Церква, Україна
https://orcid.org/0000-0002-6772-3284

Анотація. Хвороби сої знижують енергію проростання насіння та його схожість, зріджують посіви, зменшують фотосинтетичну поверхню й продуктивність культурних рослин, погіршують якісні показники. Метою досліджень було визначення впливу фунгіцидного захисту на урожайність та якість зерна сортів сої. У процесі виконання досліджень використовували наступні методи: польовий, хімічний (для визначення якісних показників зерна сої) та статистичний (для оцінки достовірності даних). Дослідження проводилися в 2021-2022 рр. в умовах ТОВ «Саварське» Обухівського району Київської області. Вивчали сорти сої Амадеа та Ауреліна та 10 варіантів фунгіцидного захисту. Виявлено, що приріст врожайності зерна сої при застосуванні фунгіцидів становить 0,41-0,72 т/га, порівняно з контролем. Найвища урожайність в досліді отримана на варіантах Селест топ 312.5 FS, ТН (1 л/т) + Абакус (2 л/га) і Стандак Топ (2 л/т) + Абакус (2 л/га) – 3,31 і 3,37 т/га та 3,06 і 3,13 т/га, відповідно у сортів Амадеа та Ауреліна. Не відмічено впливу досліджуваних фунгіцидів на вологість зерна сої та вміст жиру в насінні сої. Спостерігається зростання вмісту білку на 0,3–1,8 % на варіантах із застосуванням фунгіцидного захисту, порівняно з контролем. Найвищий вміст жиру та білка отримано на варіантах Стандак Топ (2 л/т) + Абакус (2 л/га) і Селест топ 312.5 FS, ТН (1 л/т) + Абакус (2 л/га) – 21,9 і 21,7 % та 38,5 і 42,4 %, відповідно у сортів Амадеа та Ауреліна. Результати проведених досліджень можуть бути використанні в виробничих умовах для покращення захисту посівів сої від хвороб та підвищення урожайності та якості зерна цієї культури

Ключові слова: соя; фунгіциди; продуктивність; якість зерна; передпосівна обробка насіння