Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 1, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC AND ENERGY EFFICIENCY OF FUNGICIDES AND HERBICIDES IN SOYBEAN CROPS

Mykola GRABOVSKYI[1], Olena MOSTIPAN[1], Mykola LOZINSKYI[1], Leonid KOZAK[1], Eduard FEDORENKO[2], Mykhailo OSTRENKO[1], Oleksandr GORODETSKYI[1], Lesya KACHAN[1], Denys KOVALOV[2]

[1]Bila Tserkva National Agrarian University, Bila Tserkva, Kyiv Region, Ukraine, 8/1, Sobornaya pl., Bila Tserkva, Kyiv region, 09117, Ukraine, Phone/Fax:021/3182411, E-mails: nikgr1977@gmail.com, mostipan1996@gmail.com, lozinskk@ukr.net, kla59@ukr.net, ostermi@ukr.net, o.gor@ukr.net, kaspruk70@ukr.net
[2]State Enterprise Institute of Grain Crops of the National Academy of Agrarian Sciences of Ukraine, 14, Volodymyr Vernadsky street, 49009, Dnipro, Ukraine, E-mails: eduard.fedorenko1966@gmail.com, nasinnia.izk@gmail.com

Corresponding author: nikgr1977@gmail.com

Abstract

The article presents calculations of the economic and energy efficiency of herbicide and fungicide application in soybean crops in the Ukrainian Forest Steppe. In the first experiment the soybean varieties Aurelina, EC Commander and EC Navigator and five variants of herbicide protection were studied. In the second experiment, the soybean varieties Amadea and Aurelina and ten fungicide protection variants were tested. It was found that the highest indicators of conditional net income, profitability and coefficient energy efficiency in the soybean varieties Aurelina, EC Commander and EC Navigator were obtained by using post-emergence herbicides with the active ingredient Bentazon, Imazamox (2 l/ha) + Chisalofop-P-Ethyl (2 l/ha) – 525.1, 437.6 and 558.9 EUR/ha; 87.1, 73.6 and 92.0 %; 1.83, 1.70 and 1.90. The maximum conditional net profit, profitability level and coefficient energy efficiency of the soybean varieties Amadea and Aurelina were in the variant with pre-sowing seed treatment with fungicide with the active ingredient Fipronil, Thiophanate-methyl, Pyraclostrobin (2 l/t) and the use of the active ingredient Pyraclostrobin, Epoxiconazole during the growing season – 509.0 and 421.3 EUR/ha; 76.4 and 63.1%; 2.14 and 2.02.

***Key words*:** *soybean, variety, herbicide, fungicide, grain yield, conditional net income, profitability, coefficient energy efficiency*

INTRODUCTION

Analysis of global experience shows that high economic efficiency of soybean cultivation technology is achieved through a rational combination of production and placement factors, specialization, concentration, intensification and high marketability [6, 26]. The feasibility of a technology for growing crops, in particular soybeans, is determined by the possibility of effectively reducing the unit cost of production. Production costs are formed on the basis of all material and labour resources required to organize the production process and perform all operational elements of the technology [16]. Determining economic efficiency is an indicator that will allow a full assessment of whether the recommended measures to minimize soybean stress will be in demand under production conditions, as they will be able to ensure a sustainable high level of profit [7, 18].

The most promising are the technological components of the cultivation of any crop, where the economic and energy costs of production are low and the payback of costs, profitability and energy evaluation coefficients are high [28].

Among the factors that determine the level of economic efficiency of soybean cultivation, an important role is played not only by new, highly productive varieties, but also by specific technological methods that allow their genetic potential to be fully exploited [3].

The integrated use of optimal technology elements should not only ensure high soybean productivity, but also reduce the cost of cultivation. Often, the use of unjustified technological operations leads to expensive products and, as a result, significant losses [2, 13]. The systematic application of climate-smart measures, such as the selection of new varieties, crop protection products, complex chemical and biological products, and the evaluation of fertilizer and soil management systems, ensures a high economic and energy return from soybean production [8, 17, 19].

The use of herbicides to protect soybean crops from the economic point of view ensures the level of costs of cultivation technology of 19.5-20.9 thousand UAH/ha and keeps the cost of soybean seeds at 6.4-7.3 thousand UAH/ha. Thus, when using a separate method of herbicide protection of crops with an additional need for application, the main differences in costs were formed [15].

The results of the economic analysis showed that against the background of the use of the biological fertilizer phosphate gel and the introduction of a chemical plant protection system, the total cost of gross production of the soya bean variety Oleshshya was the highest (59.4 thousand UAH/ha). The lowest indicators (25.0 thousand UAH/ha) were found in the variant of the variety Ideal without plant protection and without the use of fertilizers, which caused significant yield losses of the studied crop.Profitability reached its maximum value in the variety Oleshshya, ranging from 249 to 254%, against the background of biological and chemical plant protection, as well as seed treatment with the biological product phosphate gel. The highest rates of profitability of soybean seed production were obtained in the variant with the introduction of the biological fertilizer phosphate gel, which exceeded the control by 21.2-59.5% [29].

The most cost-effective way to grow soybeans is to bacterize the seeds with Phosphonitragin and apply $N_{30}P_{60}K_{60}$ + N_{15} in the budding phase. At the same time, the cost of production increased by 6,687 UAH/ha, but the net profit increased by 10,462 UAH/ha and the cost price decreased by 661 UAH/t, and the level of profitability was 124% [30].

In the conditions of Western Polissya of Ukraine, the most economically profitable is the cultivation of soybean varieties Cassidy and ES Mentor, with a conditional net profit of 36,743 and 35,993 UAH/ha, respectively. This was made possible by inoculating the seeds with Legum Fix and applying the chelated microfertilizer Wuksal Oilseed (2.0 l/ha) twice (BBCH 60-66) [24].

In the Ukrainian Forest Steppe, the highest soybean production costs were achieved with a seeding rate of 900 thousand/ha and chemical crop care. The same technology was used to produce products with the highest costs and the Romantika variety with a seeding rate of 800 thousand/ha and mechanical crop management had the lowest cost per tons of soybean grain [25].

The lowest cost of grain was provided by the soybean variety Svyatogor under the biological plant protection system (8.99 thousand UAH/t), while the variety Danaya under the chemical one – 9.04 thousand UAH/t. The best energy and economic indicators were also obtained in these variants: conditional net profit, profitability and energy coefficient – 25.86 and 27.39 thousand UAH/ha; 90 and 89%; 1.31 and 1.34, respectively [31].

Energy analysis is the determination of the ratio between the amount of energy accumulated in the crop yield during photosynthesis and the energy used in production. Its purpose is to measure all technological operations in terms of individual energy units. This helps us to take a balanced approach to the selection of varieties, the choice of an optimized crop management system and the use of a range of agronomic practices in the technological process. The scientific substantiation of the technological process of crop cultivation will help to optimize the energy flow through agrotechnical measures for the purpose of targeted formation of highly productive agrocenoses [11, 12, 28].

Conducting an energy assessment of technological measures for growing crops helps to compare their effectiveness and determine the feasibility of using [21]. The relevance of this approach is driven by modern production and the need to save energy per unit of crop production [24].

Determining energy input and output allows quantification of the energy efficiency of crop production [10]. Energy analysis can help to compare different technologies for growing a particular crop. One of the ways to improve the efficiency of energy use in crop production is to optimize technological methods and increase the output per unit area. Energy analysis, which is a concentrated expression of the law of energy conservation and transformation, allows us to compare energy consumption and energy content (supply) in the harvest [4, 5].

The aim was to determine the economic and energy efficiency of herbicides and fungicides in soybean.

MATERIALS AND METHODS

The research was carried out in 2021-2023 at Limited Liability Company «Savarske»Obukhiv district of Kyiv region, which is located in the soil and climatic zone of the Forest-Steppe of Ukraine. Experiment 1 ‘Efficiency of herbicide application in soybean crops’ was conducted according to the following scheme: Factor A. Soybean varieties. 1. Aurelina 2. EC Commander 3. EC Navigator Factor B. Herbicides (active ingredient). 1. Control (water treatment) 2. S-metholachlor and Terbutylazine (4.5 l/ha), before emergence of the crop 3. Dimethanamide-P (1.2 l/ha) + Pendimethalin (5 l/ha), before emergence of the crop 4. Bentazone (3 l/ha) + Fluazifop-P-butyl (1 l/ha) in the phase of 4-5 leaves of the crop 5. Bentazone and Imazamox (2 l/ha) + Chisalofop-P-Ethyl (2 l/ha), in the phase of 2-4 leaves of the crop.In experiment 2 ‘Efficiency of fungicide protection of soybean crops’ the following variants were studied: Factor A. Varieties. 1. Amadea 2. Aurelina. Factor B. Fungicides (active ingredient). 1. Control (water treatment of seeds and plants)2. Thiabendazole, Metalaxyl-M, Fludioxonil (1.25 l/t) (seed treatment before sowing) 3. Fludioxonil, Metalaxyl-M, Sedaxane (1 l/t) (seed treatment before sowing) 4. Fludioxonil, Difenoconazole, Thiamethoxam (1 litre/t) (pre-sowing seed treatment) 5. Fipronil, Thiophanate-methyl, Pyraclostrobin (2 litres/t) (seed treatment before sowing)6. Pyraclostrobin, Epoxiconazole (2 l/ha) (during the growing season) 7. Thiabendazole, Metalaxyl-M, Fludioxonil (1.25 l/t) + Pyraclostrobin, Epoxiconazole (2 l/ha) (during the growing season) 8. Fludioxonil, Metalaxyl-M, Sedaxane (1 l/t) (seed treatment before sowing) + Pyraclostrobin, Epoxiconazole (2 l/ha) (during the growing season) 9. Fludioxonil, Difenoconazole, Thiamethoxam (1 l/t) (seed treatment before sowing) + Pyraclostrobin, Epoxiconazole (2 l/ha) (during the growing season) 10. Fipronil, Thiophanate-methyl, Pyraclostrobin (2 l/t) (seed treatment before sowing) + Pyraclostrobin, Epoxiconazole (2 l/ha) (during the growing season).

Soybean crops were treated before emergence and during the growing season (2-5 leaves) with a working solution of herbicides (250 l/ha) in the experimental plots. Seed treatment with fungicides was carried out before sowing and during the growing season (before emergence) with a working solution (250 l/ha) in the experimental plots. In the control treatments, seed and crop were treated with water at a rate of 250 l/ha.

The area of the sowing plot in both experiments is 144 m^2, the accounting plot is 120 m^2 and there are three replications. The treatments were systematically arranged. The soil of the experimental plots is a typical medium loamy chernozem.

The economic assessment of soybean cultivation technology was carried out at prices as of the end of 2023 according to the following guidelines [20]. The calculation of the energy efficiency of soybean cultivation was carried out according to the method of O. K. Medvedovsky and P. I. Ivanenko [21].

RESULTS AND DISCUSSIONS

Economic indicators of soybean production efficiency include grain yield, cost of production, gross production value, price per ton of grain, notional net profit per hectare sown and profitability [9].

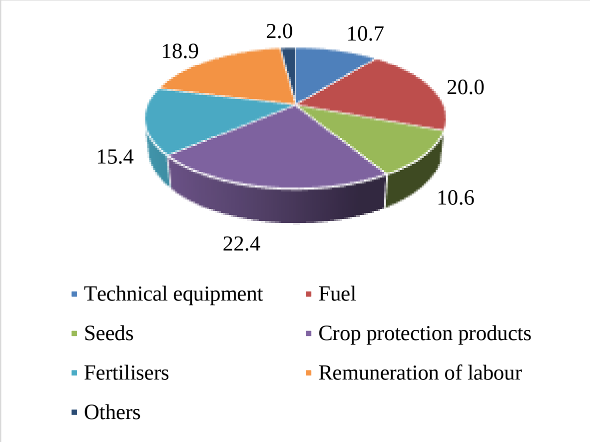

Fig. 1. Structure of economic costs in soybean cultivation
Source: Authors' own results.

In the structure of economic costs of soybean cultivation, the largest share belongs to fuel (20.0%), plant protection products (22.4%), labour (18.9%) and fertilizers (15.4%) (Fig. 1).

The share of technical inputs and seed material is 10.7% and 10.6% respectively.

When using herbicides, a balanced assessment should be made of the economic thresholds for their use, the risk of competition between weeds and crops, and the appropriateness of using protective products.

After all, a small number of weeds and the use of expensive products may not be recouped by the increase in yield [6, 23, 27].

It was found that the cultivation technology costs of the soybean varieties Aurelina, EC Commander and EC Navigator were minimal in the variants without herbicide use – 503.0, 494.8 and 507.7 EUR/ha, while the level of profitability was also the lowest - 4.8, 2.6 and 11.7% (Table 1).

Table 1. Economic efficiency of herbicide application on soybean crops (average for 2021-2023)

Variants of herbicide application	Grain yield, t/ha	Production value, EUR/ha	Costs of growing soybeans, EUR/ha	Production cost, EUR/t	Conditional net income, EUR/ha	Profitability level, %
Aurelina						
1	1.51	527.3	503.0	333.9	24.3	4.8
2	2.69	942.7	583.4	216.6	359.3	61.6
3	2.84	992.8	600.9	211.8	392.0	65.2
4	3.12	1092.0	589.5	188.9	502.5	85.2
5	3.22	1,128.2	603.0	187.1	525.1	87.1
EC Commander						
1	1.45	507.5	494.8	341.3	12.7	2.6
2	2.45	856.3	575.2	235.1	281.1	48.9
3	2.69	941.5	592.7	220.3	348.8	58.9
4	2.86	999.8	581.3	203.5	418.5	72.0
5	2.95	1,032.5	594.9	201.7	437.6	73.6
EC Navigator						
1	1.62	567.0	507.7	313.4	59.3	11.7
2	2.76	967.2	588.1	212.8	379.1	64.5
3	2.93	1,024.3	605.6	206.9	418.8	69.2
4	3.19	1,117.7	594.2	186.1	523.5	88.1
5	3.33	1,166.7	607.8	182.3	558.9	92.0

Source: Authors' own results.

In the second variant of herbicide protection (S-metolachlor and Terbutylazine (4.5 l/ha)) the costs of soybean cultivation technology were 583.4, 575.2 and 588.1 EUR/ha and the level of profitability was 61.6, 48.9 and 64.5%.

In the third variant of herbicide application (Dimethenamide-P (1.2 l/ha) + Pendimethalin (5 l/ha)) production costs increased by 5.6-9.8% compared to the control, but the conditional net profit and profitability of the studied varieties were in the range of 348.8-418.8 EUR/ha; 58.9-69.2%.

The post-emergence application of the fourth variant (Bentazon (3 l/ha) + Fluazifop-P-butyl (1 l/ha)) increased the conditional net profit and profitability to 418.5-523.5 EUR/ha; 72.0-88.1%. In the fifth herbicide application variant (Bentazon and Imazamox (2 l/ha) + Chisalofop-P-Ethyl (2 l/ha)) the highest conditional net profit and profitability indicators were obtained in the investigation – 437.6-558.9 EUR/ha; 73.6-92.0%.

Due to lower grain yields variety EC Commander had the lowest conditional net profit and profitability, ranging from 12.7 to

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 1, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

437.6 EUR/ha and from 2.6 to 73.6%. The highest values for these indicators were recorded for variety EC Navigator – 59.3-558.9 EUR/ha and 11.7-92.0%.

According to Y. R. Kandel et al. [14] and C. A. Bradley [1] fungicides can be used preventively 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 J. M. Orlowski et al. [22] fungicide use is profitable even in the absence of disease.

For the cultivation of the studied soybean varieties on the control without the use of fungicides the cost of production in the variety Amadea was 557.8 EUR/ha and Aurelina – 559.2 euro/ha the cost of one ton of seed was 225.8 and 239.8 EUR/t, respectively (Table 2). The level of profitability was the lowest in the experiment – 55.0 and 45.9%.

It should be noted that even at the lowest level of soybean yield, the control plots in the experiment showed high net income and profitability. This was made possible by the high price of soybeans, which was 350 Euro per tonne at the end of 2023. Due to lower grain yields, the Aurelina variety soybean was inferior to Amadea in terms of economic efficiency.

Table 2. Economic efficiency of fungicide application on soybean crops (average for 2021-2023)

Variants of fungicide application	Grain yield, t/ha	Production value, EUR/ha	Costs of growing soybeans, EUR/ha	Production cost, EUR/t	Conditional net income, EUR/ha	Profitability level, %
Amadea						
1	2.47	864.5	557.8	225.8	306.7	55.0
2	2.90	1,015.0	612.2	211.1	402.8	65.8
3	2.92	1,023.2	609.6	208.5	413.5	67.8
4	3.11	1,087.9	633.1	203.7	454.9	71.9
5	3.17	1,110.1	644.5	203.2	465.6	72.2
6	2.83	990.5	579.7	204.9	410.8	70.9
7	3.07	1,074.5	634.1	206.6	440.4	69.4
8	3.09	1,082.7	631.5	204.2	451.1	71.4
9	3.30	1,154.4	655.0	198.6	499.4	76.3
10	3.36	1,175.4	666.4	198.4	509.0	76.4
Aurelina						
1	2.33	816.1	559.2	239.8	256.9	45.9
2	2.70	945.6	613.6	227.1	332.0	54.1
3	2.73	954.9	611.0	224.0	343.9	56.3
4	2.91	1,018.5	634.5	218.0	384.0	60.5
5	2.94	1,029.0	645.9	219.7	383.1	59.3
6	2.66	929.8	581.1	218.7	348.7	60.0
7	2.88	1,006.3	635.5	221.1	370.7	58.3
8	2.90	1,015.0	633.0	218.3	382.0	60.4
9	3.05	1,065.8	656.4	215.6	409.4	62.4
10	3.11	1,089.1	667.8	214.6	421.3	63.1

Source: Authors' own results.

With fungicide protection, grain yield increased by 0.43-0.89 and 0.37-0.78 t/ha in the varieties Amadea and Aurelina, compared with the control. When fungicides were used both as a pre-sowing treatment of soybean seed and during the growing season there was a change in the direction of growth in the indicators that determine economic efficiency. For example, in the variety Amadea, the conditional net income and profitability increased by 96.1-158.9 EUR/ha and 10.8-17.3% compared to the control in the second to fifth variants of pre-sowing soybean seed treatment with fungicides. For the variety Aurelina this increase was 75.1-126.2 EUR/ha and 8.2-13.4%. The level of profitability of the studied varieties in the seventh to tenth fungicide application variants increased by 12.4-21.4%, compared to the control.

The highest conditional net profit and level of profitability in the second experiment was obtained in soybean varieties Amadea and Aurelina in the variant with pre-sowing seed treatment with fungicides Fipronil, Thiophanate-methyl, Pyraclostrobin (2 l/t) and the use a fungicide with the active ingredient Pyraclostrobin, Epoxiconazole during the growing season – 509.0 and 421.3 EUR/ha; 76.4 and 63.1%, respectively.

An analysis of the energy costs of soybean cultivation shows that the largest share in its structure is accounted for by fuel (30.2%), followed by fertilisers (25.7%) and technical inputs (23.1%) (Fig. 2). Plant protection products accounted for 10.3%, labour for 5.5% and seeds for 3.4%.

On average, in 2021-2023, the lowest total energy yield with harvest was in the control variants (without herbicides) in the variety Aurelina – 15.37 GJ/ha in the ECvariety Commander – 14.79 GJ/ha and in the EC variety Navigator – 16.52 GJ/ha (Table 3).

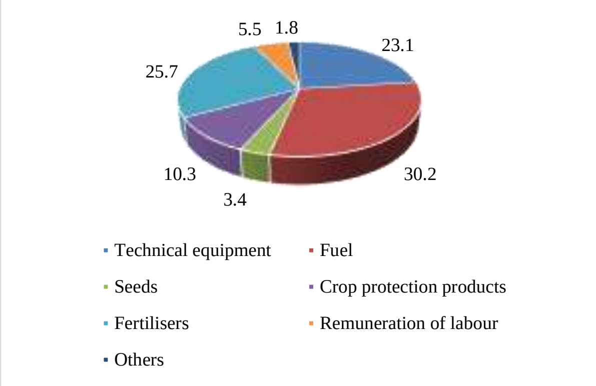

Fig. 2. Structure of energy costs in soybean cultivation
Source: Authors' own results.

Table 3. Energy efficiency of herbicide application on soybean crops (average for 2021-2023)

Variety	Variants of herbicide application	Total energy yield with harvest, GJ/ha	Total energy consumption for soybean cultivation, GJ/ha	Coefficient energy efficiency
Aurelina	1	15.37	17.64	0.87
	2	30.97	19.68	1.57
	3	32.34	19.92	1.62
	4	35.57	20.15	1.77
	5	37.07	20.21	1.83
EC Commander	1	14.79	17.23	0.86
	2	27.89	19.34	1.44
	3	30.67	19.87	1.54
	4	32.57	20.01	1.63
	5	34.22	20.08	1.70
EC Navigator	1	16.52	17.89	0.92
	2	31.78	19.90	1.60
	3	33.95	20.31	1.67
	4	37.04	20.42	1.81
	5	39.00	20.47	1.91

Source: Authors' own results.

At the same time the total energy consumption for soybean cultivation of these varieties ranged from 17.23 to 17.89 GJ/ha and the coefficient energy efficiency had minimum values of 0.87, 0.86 and 0.92, respectively. In the second and third herbicide application variants (S-metolachlor, Terbutylazine (4.5 l/ha) and Dimethanamide-P (1.2 l/ha) + Pendimethalin (5 l/ha)) the total energy yield with harvest increased by 13.10-22.48 GJ/ha, compared to the control. Taking into account the slight increase of 2.01-2.85 GJ/ha in total energy consumption for soybean cultivation compared to the control varieties, the coefficients energy efficiency of Aurelina, EC Commander and EC Navigator increased to 1.57 and 1.62, 1.44 and 1.54 and 1.60 and 1.67, respectively.

When the post-emergence herbicides Bentazon (3 l/ha) + Fluazifop-P-butyl (1 l/ha) were included in the soybean cultivation technology the coefficient energy efficiency increased and amounted to 1.77 GJ/ha for Aurelina, 1.63 GJ/ha for EC Commander and 1.81 GJ/ha for EC Navigator.

The maximum increase in the energy efficiency of soybean varieties cultivation was noted in the variants where post-emergence herbicides Bentazon and Imazamox (2 l/ha) + Chisalofop-P-ethyl (2 l/ha) were used. In the varieties Aurelina, EC Commander and EC Navigator the total energy yield with harvest was 37.07, 34.22 and 39.00 GJ/ha and the coefficient energy efficiency was 1.83, 1.70 and 1.91.

The use of fungicides also affected the energy efficiency of the soybean cultivation technology. The soybean varieties Amadea and Aurelina had the lowest total energy yields with with harvest and coefficient energy efficiency in the control –25.69 and 24.02 GJ/ha; 1.33 and 1.29 (Table 4).

The use of fungicides for pre-sowing seed treatment (third to fifth variants) helped to increase the coefficient energy efficiency to 1.87-2.04 for the variety Amadea and 1.79-

1.98 for the variety Aurelina. The use of a preparation containing the active ingredient Pyraclostrobin, Epoxiconazole (2 l/ha) on vegetative soybean plants ensured that this indicator was 1.79 and 1.73. In the seventh to tenth fungicide application variants the coefficient energy efficiency of the varieties Amadea and Aurelina was in the range of 1.95-2.14 and 1.87-2.02, respectively.

Table 4. Energy efficiency of fungicide application on soybean crops (average for 2021-2023)

Variety	Variants of fungicide application	Total energy yield with harvest, GJ/ha	Total energy consumption for soybean cultivation, GJ/ha	Coefficient energy efficiency
Amadea	1	25.69	19.34	1.33
	2	36.83	19.74	1.87
	3	37.42	19.86	1.88
	4	39.48	19.89	1.98
	5	40.28	19.78	2.04
	6	35.66	19.96	1.79
	7	39.30	20.15	1.95
	8	39.90	20.11	1.98
	9	42.55	20.22	2.10
	10	43.32	20.25	2.14
Aurelina	1	24.02	18.68	1.29
	2	34.04	19.07	1.79
	3	34.92	19.11	1.83
	4	36.96	19.10	1.93
	5	37.93	19.14	1.98
	6	33.47	19.38	1.73
	7	36.51	19.57	1.87
	8	36.83	19.60	1.88
	9	39.28	19.65	2.00
	10	39.83	19.67	2.02

Source: Authors' own results.

The highest values of total energy yield with harvest and energy coefficient efficiency were obtained during pre-sowing seed treatment with fungicides Fludioxonil, Difenoconazole, Thiamethoxam (1 l/t) and during vegetation with Pyraclostrobin, Epoxiconazole (2 l/ha) – 43.32 and 39.83 GJ/ha; 2.14 and 2.02.

CONCLUSIONS

The highest indicators of conditional net profit and profitability for soybean varieties Aurelina, EC Commander and EC Navigator were obtained using post-emergence herbicides with the active ingredients Bentazon and Imazamox (2 l/ha) + Chisalofop-P-ethyl (2 l/ha) – 525.1, 437.6, 558.9 EURs/ha; 87.1, 73.6, 92.0%.

The maximum conditional net profit and profitability were obtained in soybean varieties Amadea and Aurelina in the variant with pre-sowing treatment with the fungicide Fipronil, Thiophanate-methyl, Pyraclostrobin (2 l/t) and the use of the fungicide Pyraclostrobin, Epoxiconazole during the growing season – 509.0 and 421.3 EUR/ha; 76.4 and 63.1%.

Based on the analysis of the energy efficiency of soybean cultivation, it was determined that the most appropriate technology option is the use of post-emergence herbicides Bentazon and Imazamox (2 l/ha) + Chisalofop-P-Ethyl (2 l/ha), which ensures ancoefficient energy efficiency of 1.70-1.91.

The use of fungicides contributes to a better energy use and increases the energy intensity of the crop and the coefficient energy efficiency by 39.3-68.5 and 38.5-58.4%, respectively compared to the controls. The highest values of total energy yield with harvest and coefficient energy efficiency were obtained when the seeds were treated with Fipronil, Thiophanate-methyl, Pyraclostrobin (2 l/t) before sowing and with Pyraclostrobin, Epoxiconazole (2 l/ha) during the growing season – 43.32 and 39.83 GJ/ha; 2.14 and 2.02, respectively.

REFERENCES

[1]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.

[2]Chețan, C., Chețan, F., Rusu, T., 2015, Determining influence on the cultivation technology on weeds and soybean production. ProEnvironmentPromediu, 8(22): 211-215.

[3]Didenko, N., Lavrenko, S., Lavrenko, N., Konovalova, V., 2022, Economic and energy efficiency of soybean growing under no-till and salicylic acid in southern Ukraine. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 22(2):263-272.

[4]Ericsson, K., Rosenqvist, H., Nilsson, L. J., 2009, Energy crop production costs in the EU. Biomass and bioenergy, 33(11):1577-1586.

[5]Fernando, A. L., Duarte, M. P., Almeida, J., Boléo, S., Mendes, B., 2010, Environmental impact assessment of energy crops cultivation in EURpe. Biofuels, Bioproducts and Biorefining, 4(6):594-604.

[6]Gawęda, D., Nowak, A., Haliniarz, M., Woźniak, A., 2020, Yield and economic effectiveness of soybean grown under different cropping systems. International journal of plant production, 14(3):475-485.

[7]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.

[8]Grabovskyi, M., Marchenko, T., Panchenko, T.,Fedoruk, Y., Grabovska, T., Lozinskyi, M., Kozak, L., Kachan, L.,Gorodetskyi, O., Mostipan, O., 2023, Assessment of the efficiency of the application of fungicides and microfertilizers in sugar beet growing in the forest steppe of Ukraine. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 23(4): 365–373.

[9]Grabovskyi, M., 2018, Economic and bioenergy efficiency of growing sugar sorghum and maize as bioenergy crops at different levels of mineral nutrition. Cereals, 2(2):294-300. [in Ukrainian].

[10]Grabovskyi, M.B., Pavlichenko. K.V., Kozak, L.A., Kachan, L.M., 2022, Energy efficiency of growing maize hybrids for biogas production using macro and microfertilisers. Cereals, 1:100-107. [in Ukrainian].

[11]Hadzalo, Y., Likar, Y., Vozhehova, R., Marchenko, T., 2023, Economic and energy efficiency of the use of biologized agrotechnologies for corn cultivation . Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 23(4): 375-382.

[12]Hanegraaf, M. C., Biewinga, E. E., 1998, Assessing the ecological and economic sustainability of energy crops. Biomass and Bioenergy, 15(4-5): 345-355.

[13]Inshakov, S. V., Redkokashina, A. V., Redkokashin, A. A., Borodin, I. I., Savel'eva, E. V., 2020, The Efficiency of Innovative Soybeans Planting. International Journal of Pharmaceutical Research, 12(3). 09752366

[14]Kandel, Y. R., Hunt, K., Ames, K., Arneson, N., Bradley, C.A., Byamukama, E., Byrne, A., Chilvers, M.I., Giesler, L.J., Halvorson, J., Hooker, D.C., Kleckzewski, N.M., Malvick, D.K., Markell, S., Potter, B., Pedersen, W., Smith, D.L., Tenuta, A.U., Telenko, D.A.U., Wise, K.A., Mueller, D.S., 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.

[15]Kirichok, M.I., Remeniuk, S.O., 2022, Efficiency of herbicide application in soybean crops. Quarantine and plant protection, 3:20-25. [in Ukrainian].

[16]Lipianu, S., Zala, C.R., Istrate, R., Ciontu, C., 2023, Research on winter wheat, corn and sunflower crops protection in Ilfov county respecting national legislation. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 23, 2. 371–377.

[17]Lozinskiy, M., Burdenyuk-Tarasevych, L., Grabovskyi, M., Grabovska, T., Roubík, H., 2023., Winter wheat (T. aestivum L.) yield depending on the duration of autumn vegetation and the terms of spring vegetation recovery: 50-years study in Ukraine. Scientific Papers. Series A. Agronomy. LXVI (1):406-416.

[18]Lup, A., Miron, L., Alim, I.D., 2017, Studies and strategies regarding the evolution of crop yields per unit of land area in Romania. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 17(2): 227-234.

[19]Marcuta, L., Tindeche, C., Nuta, A.C., Nuta, F.M., Marcuta, A., 2023, Study on the importance of using agrivoltaic systems to reduce the effects of climate change. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 23(3):573-580.

[20]Matsybora, V. I., 1994, Economics of Agriculture. Kyiv, 415 p. [in Ukrainian].

[21]Medvedovsky, O. K., Ivanenko, P. I., 1988, Energy analysis of intensive technologies in agricultural production. Kyiv, 206 p. [in Ukrainian].

[22]Orlowski, J.M., Haverkamp, B.J., Laurenz, R.G., Marburger, D., Wilson, E.W., Casteel, S.N., 2016, High-input management systems effect on soybean seed yield, yield components, and economic break-even probabilities. Crop Science, 56:1988–2004.

[23]Prachand, S., Kubde, K. J., Bankar, S., 2015, Effect of chemical weed control on weed parameters, growth, yield attributes, yield and economics in soybean (Glycine max). Trends in Biosciences, 8(2): 539-542.

[24]Prymak, I., Fedoruk, Y., Grabovskyi, M., Lozinskyi, M., Lozinska, T., Prysiazhniuk, N., Pokotylo, I., Fedoruk, N., Panchenko, I., Panchenko, T., 2022, Productivity, economic and energy efficiency of short crop rotation under different systems of basic tillage and fertilization in the right bank forest steppe of Ukraine. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 22(4):617-626.

[25]Shevnikov, M.Y., Milenko, O.G., 2015, Economic assessment of soybean cultivation under different technologies. Agrobiology, 2: 83-86. [in Ukrainian].

[26]Sonawane, K. G., Pokharkar, V. G., Nirgude, R. R., 2019, An economic assessment of soybean crop production technology. Journal of Pharmacognosy and Phytochemistry, 8(4):3536-3543.

[27]Thakare, S. S., Deshmukh, J. P., Shingrup, P. V., Pawar, P. M., Ghlop, A. N., 2015, Efficacy of different new herbicides against weed flora in soybean (Glycine max L.). Plant Archives, 15(1):217-220.

[28]Venturi, P., Venturi, G., 2003, Analysis of energy comparison for crops in EURpean agricultural systems. Biomass and Bioenergy, 25(3): 235-255.

[29]Vozhegova, R. A., Kokovikhina, O. S. 2022, Economic and energy efficiency of soybean seed cultivation depending on varietal composition, fertilization and plant protection. Agrarian innovations, 14: 129–134. [in Ukrainian].

[30]Vyshnivskyi, P.S., Furman O.V., 2020, Soybean productivity depending on the elements of cultivation technology in the conditions of the right-bank forest-steppe of Ukraine. Plant and soil science, 11(1):13-22. [in Ukrainian].

[31]Zayets, S.O., Netis, V.I., 2012, Economic efficiency of growing early maturing soybean variety Dion depending on the method of sowing and seeding rate. Irrigated agriculture, 57: 267-271. [in Ukrainian].