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Agroecological assessment of the impact of harmful organisms on the bioenergy productivity of sunflower and sustainable marketing to reduce harmful impact on the environment

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ABSTRACT

On sunflower crops, the dominant phytophagous insects identified include the southern sunflower beetle (*Mordellistena parvuliformis Stscheg*. – Bar.). Research has been conducted on the biology, distribution, harmfulness, and protection measures against these pests. The disruption of agricultural techniques has led to an increase in the population of specialized phytophagous pests, particularly the southern sunflower beetle. This emergence is logical, as since 2004, the area under this crop has almost doubled, which is the main reason for the sharp increase in this pest.Highly effective and environmentally safe plant protection systems for sunflowers from harmful organisms have been developed. An effective protection system for the crop includes the application of insecticides Coragen 20 SC, Decis f-Lux 25 EC, KE, Engio 247 SC, SC, with usage rates according to the study. The use of insecticides against harmful phytophagous pests helps preserve the harvest and improve its quality. A relatively high net profit was obtained using the insecticide Coragen 20 SC (839.3 €·ha^{-1}), with a profitability level of 160% when using the insecticide. Economically profitable results were also achieved using Decis f-Lux 25 EC, KE, and Engio 247 SC, SC, where the net profit amounted to 79.8 and 694.2 €·ha^{-1} with their profitability levels at 152% and 132% respectively.

Keywords: seed treatment, fertilization, sunflower pests, insecticides, phytosanitary monitoring, bioenergy productivity, sustainable marketing, yield.

INTRODUCTION

Sunflower is one of the most important oil crops grown in countries with a temperate climate. Sunflower is a marketing oil crop that can be processed into a variety of products. It ranks fourth among oil crops in the world after soybeans, oil palm, and rapeseed. The global trend of sunflower cultivation is steadily increasing [Spitzer et al., 2018; Sikora et al., 2020; Datsko et al., 2025].

Sunflower oil is considered a premium food oil due to its high content of unsaturated fatty acids, which is considered healthy. Sunflower oil is a vegetable oil preferred by consumers worldwide [Mathew et al., 2018; Gulya et al., 2019; Baylis & Dicks, 2020; Karbivska et al., 2023].

In Ukraine, sunflower oil is the best-selling vegetable oil in the branded oil segment. By paying attention to each stage of sunflower production and applying knowledge, technology, and innovation to achieve efficiency and effectiveness of the business cycle, there is a constant need for improvement, as well as the optimization of the elements of sunflower cultivation technology in the face of climate change and the ever-growing need for quality food products for food security and export potential [Litvinov et al., 2020; Yankov & Drumeva, 2021; Zakharchenko et al., 2024].

For Ukraine, sunflower is an important technical crop. Over recent years, its cultivation area has nearly tripled. The saturation of field crop rotations with this crop increases the risk of mass infestation by harmful organisms, leading to significant crop losses and worsening the ecological situation due to the expanded use of pesticides [Mazur et al., 2021; Kolisnyk, 2024; Kolisnyk et al., 2024b].

Currently, sunflower seeds form the backbone of domestic oilseed production, accounting for almost 70% of this group's total output.

Over the past fifteen years, the area under sunflower cultivation in Ukraine has increased from 2.94 to 4.74 million hectares. Thus, the average annual area under sunflower cultivation over the last few years has been about 62% of the total area under technical crops in Ukraine. Since 2010, this area has increased by 1,767.8 thousand hectares [Radchenko et al., 2023; Kolisnyk et al., 2024a].

Sunflower is one of the most profitable crops in the domestic agricultural sector, so it's no surprise that its production continues to grow. However, this increase is not due to higher yields but rather to an increase in the area under cultivation.

However, increasing oil production is impossible without implementing the latest technologies for growing sunflower, primarily based on protecting this crop from harmful organisms [Palamarchuk et al., 2010; Ivanov et al., 2019; Palamarchuk et al., 2020; Kolisnyk et al., 2020a; Snitynskyi et al., 2023].

Given this, increasing sunflower production is advisable not by expanding the cultivated area but by increasing its yield. To obtain high yield indicators, it is necessary to create appropriate conditions for the growth and development of sunflower. This can be achieved by applying scientifically based cultivation technology, an integral part of which is effective plant protection against harmful organisms [Markell et al., 2015; Kvitko et al., 2021; Kovalenko et al., 2024].

The excessive expansion of sunflower crops has led to a situation where in many farms, its share in the structure of sown areas exceeds 30% instead of the recommended 10%. Additionally, the return of this crop to its previous cultivation site occurs every 1–3 years. Such a high concentration of sunflowers in crop rotation worsens the phytosanitary conditions in the fields and contributes to the development of pests and pathogens [Jursík et al., 2015; Turak et al., 2025].

The development and implementation of modern phytosanitary monitoring systems solve the problems of forecasting risks associated with mass pest outbreaks.

The research aimed to refine the species composition of sunflower pests and their main types, whose mass reproduction causes significant economic damage due to reduced yield and seed quality deterioration, as well as to develop effective protection measures for sunflowers by solving the following tasks: refine the biology, ethology, ecology, and long-term and seasonal dynamics of the main pests' populations; establish the harmful zones of phytophagous; improve monitoring methods and develop key elements of pest development forecasting; investigate the role of agricultural practices in limiting the number and harmfulness of phytophagous;study and evaluate the effectiveness of modern insecticides in protecting sunflowers from pests; develop recommendations for applying protective measures against harmful agents to sunflowers.

MATERIAL AND METHODS

In the course of the studies, generally accepted entomological methods were used: field – phenological observations of phytophagous, soil diggings, counting with the help of pheromone traps, evaluation of the effectiveness of agricultural practices, research on the effectiveness and duration of toxic action of insecticides.

The studies were conducted in production conditions at LLC "Organic-D" in Hnivan, Vinnytsia region (2023–2024).

Mineral fertilizers were applied in the spring during cultivation. In forming different variants of the experiment, we used both mixed granular fertilizers and simple forms of fertilizers.

In the field experiments, laid out on production sunflower crops, the emergence of migrating beetles on the plants, the beginning and duration of egg-laying by the southern sunflower beetle were observed.

The extent of plant damage and the number of preimaginal stages of the weevil (egg-laying, larvae) were determined by examining and dissecting stems with a knife and counting the detected insects.

The insecticidal action of chemical agents was established by reducing the number of pests compared to the control.

Also, in various variants of chemical protection, the productivity of the culture was determined, and the seed yield losses from phytophage damage were evaluated.

The soil of the experimental field – typical medium-humus chernozems, with a profile depth of 100–120 cm. The content of humus 4.2–4.4%, phosphorus and potassium respectively 0.15–0.1% and 2.1–2.2% pH of the arable soil layer – 6.9–7.0. Chernozems are distinguished by good water permeability and aeration, high moisture capacity. In the 0–150 cm layer, they can retain up to 500 mm of water, i.e., the annual precipitation reserve.

The soils of the farm have high potential fertility. Soil – chernozems light-humus weakly-eroded heavy-loamy on loess, has favorable physico-chemical properties for sunflower cultivation [Kolisnyk et al., 2020b; Tykhonova et al., 2021; Palamarchuk et al., 2022; Datsko et al., 2024a].

The climate of the Right-Bank Forest-Steppe of Ukraine is moderately continental with noticeably pronounced dry-windy phenomena. It is formed under the influence of a relatively large amount of solar radiation, the dominance of continental air of moderate latitudes, and is characterized by a hot summer with drought and moderately cold winter with unstable snow cover. The temperature regime is unstable and characterized by significant fluctuations throughout the year. The change of seasons occurs gradually, without harsh changes. The frost-free period lasts 150–170 days. According to long-term research, the maximum air temperature did not exceed +38 °C, the minimum did not drop below -35 °C. The coldest month is January, the warmest is July. The average long-term temperature in January is -3.8 °C, in July +22.4 °C.

The yield of agricultural crops in the study area depends 50–60% on meteorological factors. To achieve high yield levels of agricultural crops under conditions of sufficient plant moisture, the temperature regime of the zone is quite favorable [Lys et al., 2024; Datsko et al., 2024b].

RESULTS AND DISCUSSION

To determine the field germination of sunflower seeds on the experimental plots, counts of the number of sprouts were conducted. During the inspections, it was found that the field germination was inferior to the laboratory germination indicators [Voitovyk et al., 2023; Zakharchenko et al., 2024; Sobko et al., 2025]. In laboratory conditions, compared to the field, more favorable conditions for germination and similarity of seeds were created due to favorable temperature and sufficient moisture (Table 1).

Analyzing the results of the counts, it can be concluded that on the 5th day after sowing, the number of sunflower sprouts on variants with seeds treated with Gaucho 70 WS was higher by 11.2%, and with Cruiser 350 FS by 3.7% compared to the control. Further studies showed that field germination increased in all variants. Sunflower seeds treated with Gaucho 70% had the maximum field similarity, amounting to 85.7%.

The results of the studies showed that the application of neonicotinoid group substances leads to an increase in the germination energy of sunflower seeds by 2.6–5.6%, compared to the control.

One of the most effective methods of controlling the population of the southern sunflower beetle is the application of insecticides. During 2023–2024, the entomocidal action against the imago of the southern sunflower beetle of broad-spectrum insecticides was studied.

Spraying was conducted in the third decade of June at the beginning of massive larval hatching, coinciding with the 10–12 leaf stage of the crop - under moderately warm and sunny weather conditions.

As seen in Table 2, the testing of insecticides against the imago of the thistle beetles showed a very high result, exceeding 90% effectiveness. At the same time, the Coragen 20, SC preparation, which has almost 100% effectiveness against the imago of the weevil, combines it with a high

Table 1. Effect of insecticide treatment of sunflower seeds on field germination, 2023–2024

Variant	Field similarity on the 5th and 10th day after sowing, %					
	5th			10th		
	2023	2024	Average	2023	2024	Average
Control (untreated)	60.6	62.4	61.5	78.4	82.2	80.3
Cruiser 350FS, (thiamethoxam, 350 g·l^{-1}) – 2.0 kg·t^{-1}	66.8	64.0	65.4	80.0	84.4	82.2
Gaucho 70WS, (imidacloprid 700 g·kg^{-1}) – 2.0 l·t^{-1}	72.0	73.4	72.7	84.8	86.6	85.7

Table 2. Effectiveness of insecticides against the imago of the southern sunflower seed weevil (*Mordellistena parvuliformis*), 2023–2024

Variant	Usage rate, l, kg·ha^{-1}	Number of imago per day of accounting, ex./100 plants		
		Before treatment	3 day	5 day
2023				
Control	–	26.5	34.0	30.0
Engio 247 SC, CS	0.2	14.00	2.65	1.40
Decis f-Lux 25 EC, CE	0.5	16.25	4.00	1.32
Coragen 20 CS	0.2	20.25	2.15	1.20
2024				
Control	–	32.2	37.1	40.4
Engio 247 SC, CS	0.2	30.6	2.44	1.28
Decis f-Lux 25 EC, CE	0.5	33.1	4.12	1.54
Coragen 20 CS	0.2	28.4	2.10	1.12

tolerance for the beneficial entomofauna of the sunflower field agrobiocenosis.

Regarding the effectiveness of this preparation against larvae, counts even after two months showed that on variants with Coragen 20, CS (0.2 l·ha^{-1}) twice as few plants were damaged compared to the control under conditions of preserved beneficial entomofauna (Table 3).

As the data show, the results of testing insecticides Coragen 20, CS, Decis f Lux 25 EC, CE, and Engio 247 SC, CS against larvae of the southern sunflower seed weevil on the 3rd day after treatment were low and did not exceed 35%. This can be associated with the fact that in such a relatively short period, the systemic-contact insecticides based on thiamethoxam had not yet penetrated into the internal tissues of the plants and could not cause significant mortality of larvae.

Three weeks after treatment (in mid-July), at the beginning of flowering, the effect of insecticides significantly increased. In all variants, the effectiveness calculated by reducing the number of egg-laying compared to the control reached the maximum indicator when using an increased rate of insecticides Coragen 20 CS, Decis f Lux 25 EC, CE, and Engio 247 SC, CS.

Two months after treatment (at the end of August), throughout all years, the highest effectiveness was shown by Coragen 20, CS with usage rates of 0.15 and 0.20 l·ha^{-1}. This can be explained by the systemic nature of the active ingredient, which the preparations Decis f Lux 25 EC, CE and Engio 247 SC did not possess.

The data presented in Table 4 are in all cases recalculated for basic moisture content (7%) and impurity level (1%). Somewhat unexpectedly, the most productive year turned out to be 2024, which was not particularly favorable in terms of climatic conditions.

The use of chemical protection of the sunflower agroecosystem against pests also

Table 3. Effectiveness of insecticides against larvae of the southern sunflower seed weevil (*Mordellistena parvuliformis*) (2023–2024)

Variant	Before spraying			3 weeks after spraying			2 months after spraying	
	Damaged plants, %	Number of larvae, ex./plant	Number of egglaying, pcs./plant	Damaged plants, %	Number of larvae, ex./plant	Number of egglaying, pcs./plant	Damaged plants, %	Number of larvae, ex./plant
Control	29.6	0.85	0.65	54.4	1.74	0.39	91.6	3.62
Coragen 20, CS (0.15 l·ha^{-1})	28.0	0.87	0.54	47.2	1.64	0.30	44.4	1.18
Coragen 20, CS (0.2 l·ha^{-1})	27.6	0.84	0.68	43.7	1.44	0.27	44.9	1.07
Decis f Lux 25 EC, CE (0.3 l·ha^{-1})	25.9	0.95	0.64	37.4	1.32	0.23	54.0	1.68
Decis f Lux 25 EC, CE (0.5 l·ha^{-1})	27.6	0.82	0.78	33.1	0.83	0.20	47.4	1.72
Engio 247 SC, CS (0.18 l·ha^{-1})	25.9	0.86	0.66	28.3	0.57	0.16	73.0	2.28
Engio 247 SC, CS (0.2 l·ha^{-1})	26.5	0.83	0.59	28.2	0.44	0.13	80.3	2.15

Table 4. Yield of conditional sunflower seeds depending on the effectiveness of insecticides, t·ha^{-1}

Variant	Years		Average 2023–2024	+/- to control
	2023	2024		
Control	2.38	2.40	2.39	–
Coragen 20, CS (200 g·l^{-1} chlorantraniliprole)	3.09	3.11	3.10	0.71
Decis f Lux 25 EC, CE (25 g·l^{-1} deltamethrin)	2.98	3.02	3.00	0.61
Engio 247 SC, CS (141 g l^{-1} thiamethoxam; 106 g·l^{-1} lambda-cyhalothrin)	2.76	2.78	2.77	0.38

affected the bioenergetics of the crops, specifically the oil yield and the efficiency of biodiesel conversion (Table 5).

From the table, it is evident that the use of chemical protection on sunflower crops can positively influence the oil yield and subsequently the efficiency of conversion to biodiesel.

However, while considering this, it is important to consider the potential consequences for the environment and human health. The highest oil yield was obtained in the variant protected with Engio 247 SC, CS (141 g·l^{-1} thiamethoxam; 106 g·l^{-1} lambda-cyhalothrin), Decis f Lux 25 EC, CE, and Coragen 20, CS – 45.7% relative to cleaned sunflower seeds, which is 14.1% more than the control without the application of herbicides.

The cost of production (calculated at €488.1 per ton of conditional seed) ranges from €1,166.5 to €1,513.1 ha^{-1}. The level of balanced efficiency indicators can be calculated only on the basis of a comparison of the cost of production and production costs (Table 6).

On sunflower crops in the control variants of the experiment, the minimum indicators of the level of profitability were recorded – 108% and conditional net profit – €607.0.

The highest indicators of stable efficiency were obtained in the experimental version using the product Coragen 20, CS (200 g·l^{-1} chlorantraniliprole).

Calculations of the effectiveness of the use of drugs prove that the use of insecticides on sunflower crops, namely Decis f Lux 25 EC, SE (25 g·l^{-1} deltamethrin) and Coragen 20, KS (200 g·l^{-1} chlorantraniliprole) allows for a sustainable reduction in harmful effects on the environment.

Table 5. Bioenergy productivity of sunflower hybrid crops depending on the applied preparations

Variant	Application rate of the product	Oil yield, %*
Control	–	31.4
Engio 247 SC, CS (141 g·l^{-1} thiamethoxam; 106 g·l^{-1} lambdacyhalothrin)	(141 g l^{-1} thiamethoxam; 106 g·l^{-1} lambdacyhalothrin)	45.5
Decis f Lux 25 EC, CE	(25 g·l^{-1} deltamethrin)	41.5
Coragen 20	(200 g·l^{-1} chlorantraniliprole)	40.6

Note: *Percentage relative to cleaned sunflower seeds.

Table 6. Evaluation of the effectiveness of integrated pesticide application on sunflower crops

Effectiveness indicator (per 1 ha)	Variants of the experiment			
	Without product (control)	Coragen 20, cs (200 g·l^{-1} chlorantraniliprole)	Decis f lux 25 ec, ce (25 g·l^{-1} deltamethrin)	Engio 247 sc, cs (141 g·l^{-1} thiamethoxam; 106 g·l^{-1} lambdacyhalothrin)
Yield, t	2.39	3.10	3.00	2.77
Yield increase, t	–	0.71	0.61	0.38
Product value, €	1166.5	1513.1	1464.3	1352.0
Production expenses, thousand €	559.5	578.6	576.2	577.4
Cost, €	234.1	186.6	192.1	208.5
Conditional net profit, €	607.0	934.5	888.1	774.6
Profitability, %	108	162	154	134

CONCLUSIONS

The use of chemical protection of the sunflower agroecosystem against pests also affected the bioenergetics of the crops, specifically the oil yield and the efficiency of biodiesel conversion

The highest oil yield was obtained in the variant protected with Engio 247 SC, CS (141 $g \cdot l^{-1}$ thiamethoxam; 106 $g \cdot l^{-1}$ lambda-cyhalothrin), Decis f-Lux 25 EC, CE, and Coragen 20, CS – 45.7% relative to cleaned sunflower seeds, which is 14.1% more than the control without the application of herbicides.

Highly effective and environmentally safe systems for protecting sunflower plants from harmful organisms have been developed. A sustainable and effective crop protection system is the use of insecticides Koragen 20 SK, Decis f-Lux 25 ES, KE, Engio 247 SK, SK with the use rates according to the study. The use of insecticides against harmful phytophagous pests contributes to the preservation of the crop and improvement of its quality.

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