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ABSTRACT

of a dissertation for the award of the educational and scientific degree "Doctor"
Professional field: 6. Agricultural Sciences and Veterinary Medicine
6.2. Plant Protection

INNOVATIVE METHODS FOR THE CONTROL OF ECONOMICALLY IMPORTANT PESTS OF WINTER OILSEED RAPE

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PLOVDIV, 2024

The studies were carried out during the period 2019-2023 under field conditions in the regions of Plovdiv, Stara Zagora and Ruse. The object of research are modern eco-friendly PPPs for the control of economically important pests of oilseed rape and agricultural practices corresponding to the strategy of integrated pest management in this crop. The species composition of pest and beneficial entomofauna on winter oilseed rape and the effect of flowering plant species on main groups of pollinators and predators were studied, and the efficacy of potassium salts of aliphatic carboxylic acids (or fatty acids) against pollen beetle and brassica pod midge was tested.

The dissertation has a volume of 108 pages, contains 43 tables, 17 figures and 44 photographs. The cited literature includes 92 sources, of which 2 are in Cyrillic and 90 are in Latin.

INTRODUCTION

The economic importance of oilseed rape worldwide is constantly increasing as a result of its increased demand. On the other hand, growth is also driven by the increasing needs of vegetable oils and protein for both animals and humans.

Canola is a crop that is exposed to significant biotic stress caused by both pathogens and insect pests. The possibilities of controlling pathogens are significantly greater compared to enemies, which actually turns the latter into a real challenge for plant protection. As the usual methods and means used for integrated pest management such as crop rotation, tillage, resistant varieties or biocontrol are ineffective or unavailable, insect control is largely still based primarily on the use of insecticides.

In 2013, the European Food Safety Authority (EFSA) declared neonicotinoids as products of unacceptably high risk to wild and honey bees (EFSA, 2018). In 2013 and 2016, the European Commission and the French government restricted the use of several substances belonging to the chemical category of neonicotinoids. Regulation (EC) 485/2013 of the European Union restricts the use of clothianidin, thiamethoxam and imidacloprid, while France since 2018 has banned acetamiprid and thiacloprid in addition to these three active substances (Demortain, 2021). Foliar treatments with plant protection products containing these active substances have been prohibited for crops attractive to bees and for cereals with the exception of uses in greenhouses and uses after flowering.

Therefore, the search for alternative means of control corresponding to the strategy of integrated pest management, as well as the inclusion of appropriate agricultural practices contributing to the protection of the beneficial entomofauna (conservation) in this crop is of extreme practical importance.

1. AIM AND OBJECTIVES

The aim of the present study is to investigate innovative alternative methods for the control of economically important pests of winter oilseed rape and agricultural practices corresponding to the integrated pest management strategy of the crop.

In connection with the implementation of the set aim, the following objectives have been defined:

- Study of pest and beneficial entomofauna on winter oilseed rape in the region of Plovdiv;
- Testing of the efficacy of eco-friendly insecticides for the control of pollen beetle *Brassicogethes aeneus* (Fabricius, 1775);
- Testing of the efficacy of eco-friendly insecticides for the control of brassica pod midge *Dasineura brassicae* (Winnertz, 1853);
- Study of the effect of flowering plant species on the beneficial entomofauna of winter oilseed rape.

2. MATERIAL AND METHODS

2.1. Species composition of pest and beneficial entomofauna on winter rape in the region of the city of Plovdiv

The studies of the species composition of the entomofauna in oilseed rape agrocenosis were conducted in 2020-2023 in the region of Plovdiv, where most of the experiments for testing the efficacy of eco-friendly PPPs against economically important pests were carried out.

Surveys to report the species composition of pest and beneficial entomofauna on rapeseed were carried out every 14 days from the beginning of the growing season until the harvest of the crop. Two monitoring methods, visual sampling and sweep-net sampling, were used. To estimate the population densities of some pests it were made a minimum of 100 sweeps in a field (e.g., five subsamples of 20 sweeps). The average population density is

calculated per 1 m^2. The species requiring microscopic technique for their identification were transported and stored in the laboratory of the Department of Entomology.

2.2. **Testing of the efficacy of eco-friendly insecticides for the control of pollen beetle *Brassicogethes aeneus***

The tests were conducted in the period 2019-2021 in the regions of Plovdiv and Ruse. The experiment included 5 variants (along with the untreated control) (Table 1). Trials were performed following EPPO standard PP 1/178(3) - *Meligethes aeneus* (syn. *Brassicogethes aeneus*) on rapeseed.

Plots representing replicates for the individual variants were 10x3 m in size, arranged in a randomized block. Each variant includes 4 replicates spaced at a distance of 1 m between variants and 2 m between replicates.

Table 1. List of PPPs tested against the pollen beetle

	Variants	**Active ingredient**	**Dose**	**Number of applications**
1	Untreated control			
2	Potassium salts of aliphatic carboxylic acids (fatty acids) C_{14}-C_{20}	460 g/l potassium salts of aliphatic carboxylic acids C_{14}-C_{20}	2,5 l/ha	1 2 (7 days after the first treatment)
3	Potassium salts of aliphatic carboxylic acids (fatty acids) C_{14}-C_{20}	460 g/l potassium salts of aliphatic carboxylic acids C_{14}-C_{20}	5 l/ha	1 2 (7 days after the first treatment)
4	Decis 100 EC (reference product)	100 g/l deltamethrin	0,05 l/ha	1
5	Mavrik 2 F (reference product)	240 g/l tau-fluvalinate	0,2 l/ha	1

The potassium salts of aliphatic carboxylic acids (fatty acids) with a carbon chain length of C_{14} - C_{20} act only in direct contact with pests. Lipophilic carbon chains penetrate and disrupt the lipoprotein matrix of insect cell

membranes. The first visible effect is the immediate cessation of feeding. The death of the insect is the result of rapid dehydration of the body.

Their category of use as PPPs (Plant Protection Products) is non-professional, and their application does not require a quarantine period. All this defines them as an effective alternative to chemical PPPs, representing a new concept in modern integrated pest management systems in canola.

The experiment was carried out in 4 locations, distributed as follows: three in the Plovdiv region (Zhelyazno village, Trud village, Plovdiv city) respectively in 2019, 2020 and 2021 and one in the Ruse region (Trastenik village) in 2020. The hybrids DK Expower, ES Capello, SI Harness and DK Implement CL were used. GAP (Good Agricultural Practice) was followed in the maintenance of the experiment except for insecticides.

The evaluation of the efficacy of the products against pollen beetle was carried out in accordance with the EPPO standard PP 1/178(3). The Henderson-Tilton formula was used to calculate efficacy of the tested products. The number of live beetles was recorded on 50 main shoots randomly selected from the center of each plot. Population density is represented as the number of adults per 50 shoots. The value is averaged over all replicates (plots) of the respective variant. Assessments were carried out early in the morning under the same climatic conditions in each variant.

Time and frequency of assessment:

- Assessment just before the first application of the test products;
- 1st assessment – 1 to 3 days after first application;
- 2nd assessment – 5 to 7 days after frist application and at the day of second application;
- 3rd assessment – 10 – 11 days after first application and 3 – 4 days after second application;
- 4th assessment – 14 – 15 days after first application and 7 – 8 days after second application;

2.2. Testing of the efficacy of eco-friendly insecticides for the control of brassica pod midge *Dasineura brassicae*

The tests were conducted in the period 2020-2022 in two locations in the region of the city of Plovdiv (in 2020 and 2021, respectively) and one in the village of Koprinka,, Stara Zagora region, (in 2022).

Five variants were included in the experiment, along with one untreated control (sprayed with water) (Table 2). The experiments were carried out following the EPPO standard -PP 1 / 220 (1) - *Dasineura brassicae*.

Tible 2. List of PPPs tested against the brassica pod midge

	Variants	**Active ingredient**	**Dose**	**Number of applications**
1	Untreated control			
2	Potassium salts of aliphatic carboxylic acids (fatty acids) C_{14}-C_{20}	460 g/l potassium salts of aliphatic carboxylic acids C_{14}-C_{20}	2,5 l/ha	1 2 (5 days after the first treatment)
3	Potassium salts of aliphatic carboxylic acids (fatty acids) C_{14}-C_{20}	460 g/l potassium salts of aliphatic carboxylic acids C_{14}-C_{20}	5 l/ha	1 2 (5 days after the first treatment)
4	Decis 100 EC (reference product)	100 g/l deltamethrin	0,05 l/ha	1
5	Mavrik 2 F (reference product)	240 g/l tau-fluvalinate	0,2 l/ha	1

The evaluation of the efficacy of the products against the brassica pod midge was carried out in accordance with the EPPO standard PP 1/220(1). Pods damaged by the larvae of the brassica pod midge were recorded. At first they turn yellowish and somewhat swollen, then become stunted, turn brown, and break open prematurely. The pods were opened and, based on the morphological characters of the larvae, it was confirmed that the damage was indeed from *D. brassicae*, not from the weevil *C. assimilis* (whose larvae have

a distinct head capsule, which the midge larvae do not). Shortly before application 25 main shoots per plot were marked on which the observations were conducted.

Before the first treatment, all damaged pods from the marked shoots were counted and removed. The procedure was repeated for each subsequent checking. The number of damaged pods is presented as an average value for the individual variants - average number of damaged pods per 25 shoots. Efficacy was calculated using Abbot's formula.

Time and frequency of assessment:

- Assessment before frist application of the test products;
- 1st assessment – 4 to 6 days after first application and at the day of the second one;
- 2nd assessment – 14 to 16 days after frist application.

2.3. Effect of flowering plant species on the beneficial entomofauna of winter oilseed rape

The study is part of the work on an international project under the Horizon 2020 program: EcoStack "Stacking of ecosystem services, mechanisms and interactions for optimal crop protection, pollination enchancement, and productivity“ and was conducted under field conditions at the Agricultural University of Plovdiv in 2021- 2023.

Applying agricultural practices that balance the management of pest populations of winter canola, which has traditionally applied large amounts of non-selective pesticides, with the requirements of pollinating insects and bioagents that feed both in the crop and on neighboring flowering plants is an approach, meeting the requirements of modern biorational agriculture. Sowing strips of flowering plants along field borders or within a crop represents a promising tool to support populations of natural enemies in the agrocenosis and thus to improve conservation biological control. The conducted

experiment aims to establish under field conditions the ability of a relatively large number of flowering annual plants to attract beneficial entomofauna and to be a habitat and source of food, a condition for preserving the populations of predatory insects and pollinators.

- **Design of the field experiment**

In a crop of winter oilseed rape (EC Capello variety) created for the purposes of the experiment, 4 strips of flowering plant species were sown. Each of these strips includes 21 plant species (Table 3), sown in separate squares, each with an area of 1 m^2 (1m x 1 m), separated from each other and from the rape by 1 m (Photo 1 and Fig. 1).

Photo 1. Sowing the strips with flowering plant species

The four flowering strips represent four replicates of the studied plants and are spaced 5 m apart. In Fig. 1 is the scheme of the described field experiment.

- **Assessment of beneficial entomofauna**

Observations on the beneficial entomofauna started from the beginning of flowering of the plants sown in the strip squares in the canola crop and were carried out weekly or biweekly until the end of flowering of the respective plant species.

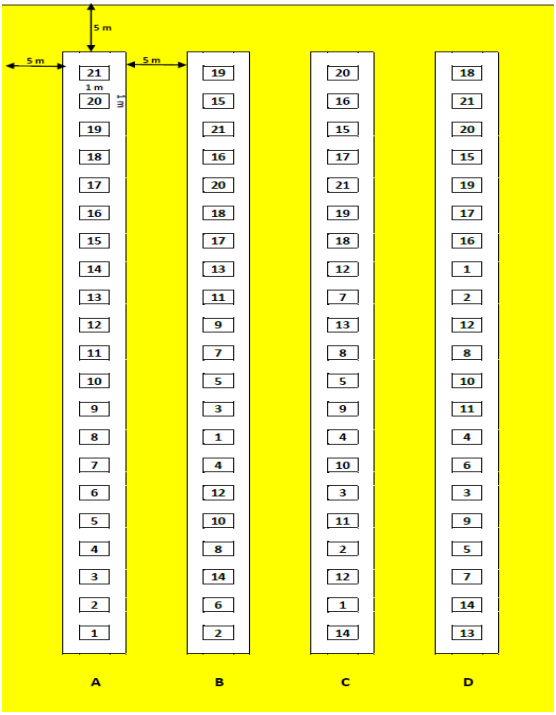
Two methods were used to identify and count pollinators and other visitors (predators and parasitoids) of flowering plants.

The first method is direct visual observation of flowering plants and counting the number of the main groups of pollinators (honeybees, bumblebees, syrphid flies, nectar-feeding flies and butterflies), parasitoids and more important predators (ladybugs, lacewings, predatory bugs, etc.).

Table 3. List of flowering plant species included in the field experiment conducted at the Training and experimental fields of the Agricultural University, Plovdiv in 2021-2023

№	Flowering plant species	
	Latin name	**Common name**
1	*Foeniculum vulgare*	Fennel
2	*Coriandrum sativum*	Coriander
3	*Anethum graveolens*	Dill
4	*Matricaria chamomilla*	Chamomile
5	*Pimpinella anisum*	Anise
6	*Fagopyrum esculentum*	Buckwheat
7	*Calendula officinalis*	Marigold
8	*Sinapis alba*	White mustard
9	*Phacelia tanacetifolia*	Lacy phacelia
10	*Malva sylvestris*	Common mallow
11	*Borago officinalis*	Borage, starflower
12	*Taraxacum officinale*	Dandelion
13	*Cuminum cyminum*	Cumin
14	*Hyssopus officinalis*	Hyssop
15	*Arnica montana*	Mountain arnica
16	*Nigella damascene*	Black cumin
17	*Echium plantagineum*	Purple viper's-bugloss
18	*Centaurea cyanus*	Bachelor's button
19	*Trifolium pratense*	Red clover
20	*Linum sp.*	Linum, flax
21	*Onobrychis viciifolia*	Common sainfoin

Figure 1. Scheme of the field experiment conducted at the Agricultural University of Plovdiv in 2021-2023



In the second method, insects were collected using a sweep net and placed in small bottles of ethyl alcohol (or stored dry) for further identification.

The results were processed statistically and the data were analyzed by one-way analysis of variance (one-way ANOVA, Tukey HDS (Honestly Significant Difference) at a significance level of α = 0.05) with the statistical software package IBM SPSS Statistics 19.

3. RESULTS AND DISCUSSION

3.1. Pest and beneficial entomofauna of winter oilseed rape in the region of Plovdiv

During the period 2020-2023, 23 species of insect pests from 5 orders and 11 families were found in the agrocenosis of oilseed rape in the region of Plovdiv (Table 4, Photos 2-15).

Table 4. Species composition of pest entomofauna on winter oilseed rape, registered in the region of Plovdiv in 2020-2023

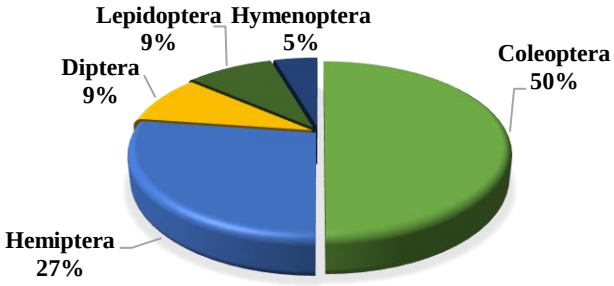
Order	**Family**	**Species**
Hemiptera	Aphididae	*Brevicoryne brassicae* (Linnaeus, 1758)
	Pentatomidae	*Eurydema ornatum* (Linnaeus, 1758)
		Dolycoris baccarum (Linnaeus, 1758)
		Carpocoris mediterraneus Tamanini, 1958
	Miridae	*Lygus pratensis* (Linnaeus, 1758)
	Rhopalidae	*Corizus hyoscyami (Linnaeus, 1758)*
Coleoptera	Nitidulidae	*Brassicogethes aeneus* (Fabricius, 1775)
	Chrysomelidae	*Psylliodes chrysocephala* Linneaus, 1758
		Phyllotreta undulata (Kutschera, 1860)
	Curculionidae	*Ceutorhynchus obstrictus* (Marsham 1802)
		Ceutorhynchus pallidactylus (Marsham 1802)
		Ceutorhynchus assimilis (Paykull, 1792)
		Ceutorhynchus napi Gyllenhal 1837
		Ceutorhynchus typhae (J.F.W.Herbst, 1795)
		Ceutorhynchus erysimi (Fabricius, 1787)
	Cetoniidae	*Tropinota hirta* (Poda, 1761)
		Oxythyrea funesta (Poda, 1761)
		Valgus hemipterus (Linnaeus, 1758)
Lepidoptera	Pieridae	*Pieris rapae* (Linnaeus, 1758)
		Pieris brassicae (Linnaeus, 1758)
Hymenoptera	Tenthredinidae	*Athalia rosae* (Linnaeus, 1758)
Diptera	Cecidomyiidae	*Dasineura brassicae* (Winnertz, 1853)
	Anthomyiidae	*Delia radicum* (Linnaeus, 1758)

Photo 2. Adult of pollen beetle *Brassicogethes aeneus*

Photo 3. Adults of pollen beetle on canola flower buds

Order Coleoptera has the largest number of species in the entomofauna - 50% of the total number of species registered during the study period, followed by order Hemiptera - 27% (Fig. 2).

Figure 2. Percentage ratio of pest entomofauna, presented as the number of registered insect species, on winter oilseed rape in the region of Plovdiv in 2021-2022



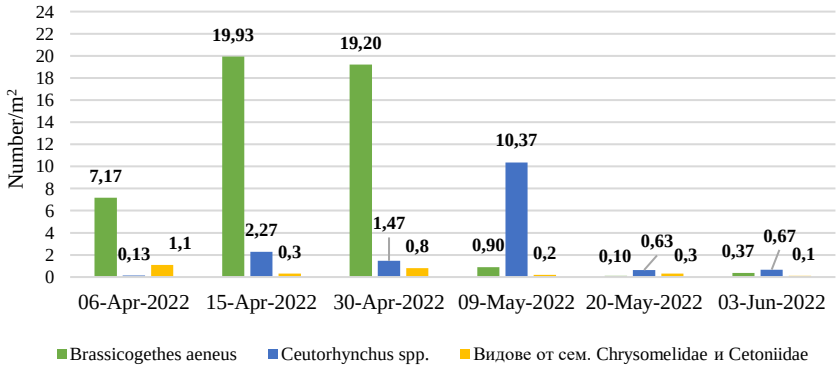
During the vegetation of 2021-2022, the population density of pests from the order Coleoptera was monitored and it was found that the pollen beetle *Brassicogethes aeneus* (Photos 2-3) and the weevils of the genus

Ceutorhynchus (Photos 4-8) were dominant. The average population density of the pollen beetle reaches almost 20 adults/m^2, and of the weevils up to 10 adults/m^2 (Fig. 3).

Photo 4. Adult of weevil *Ceutorhynchus pallidactylus*

Photo 5. Adult of the weevil *Ceutorhynchus obstrictus*

Figure 3. Population density of economically important Coleoptera species recorded in the agrocenosis of winter oilseed rape in the Plovdiv region in 2022



The dominant species of the weevils of the genus *Ceutorhynchus* is *C. pallydactilus* - more than 50% of all recorded individuals, followed by *C. obstrictus*. Out of the total number (466) collected during the reporting of the

population density of weevils, 282 were cabbage stem weevil, and 144 cabbage seedpod weevil.

Photo 6. Adult of the weevil *Ceutorhynchus typhae*

Photo 7. Adult of the weevil *Ceutorhynchus sp.*

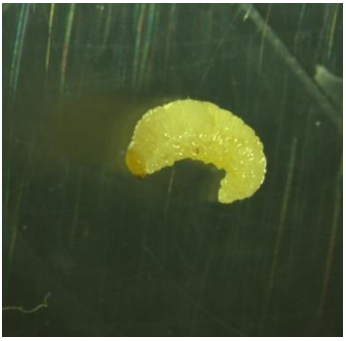


Photo 8. Larva of *Ceutorhynchus* sp.

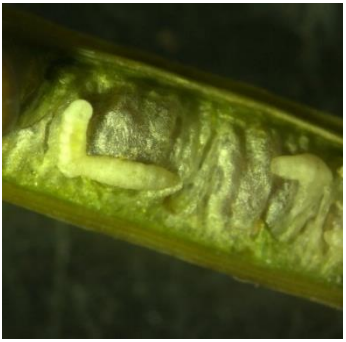


Photo 9. Larva of the brassica pod midge

In the fall, as soon as the winter rape sprouts, adults of the flea beetles *Psylliodes chrysocephala* and *Phyllotreta* spp. appear on the plants. (Photos 10-11), while weevils attack the crop in spring and increase in density as the growing season progresses.

Photo 10. Adult of the flea beetle *Psylliodes chrysocephala*

Photo 11. Canola plant damaged by *Psylliodes chrysocephala*

During flowering, the entomofauna is extremely diverse and includes both phytophagous insects, including economically important pests (pollen beetle, cabbage seedpod weevil, brassica pod midge) attacking the generative organs, as well as many beneficial species - predators, parasitoids and pollinators.

Photo 12. Aphid colony on canola shoots

Photo 13. Adult of *Eurydema ornata*

The beneficial entomofauna observed on oilseed rape in the region of Plovdiv includes both predatory and parasitoid species (Photos 16-19).

Fourteen species of predatory insects from 4 orders and 7 families were found. The Coleoptera order has the largest number of identified species (Table 5).

Photo 14. Възрастно на *Lygus pratensis*

Photo 15. Възрастно на *Oxythyrea funesta* по цвят на рапица

Photo 16. Изменчива калинка *Hippodamia variegata*

Photo 17. Седемточкова калинка *Coccinella septempunctata*

The predatory entomofauna is mainly represented by species having a wide food specialization, such as lacewings (Chrysopidae), soldier beetles (Cantharidae) and predatory bugs (Miridae, Nabidae). Predatory ladybirds (Coccinellidae) and syrphid flies (Syrphidae) are specialized aphidophagous

insects, and tachinid flies and more specifically the species *Ectophasia crassipennis* is known as a parasite on adults of bugs from the families Pentatomidae, Coreidae, Lygaeidae.

Photo 18. Възрастно на *Rhagonycha fulva* по рапица

Photo 19. Възрастно на *Harmonia axyridis* по рапица

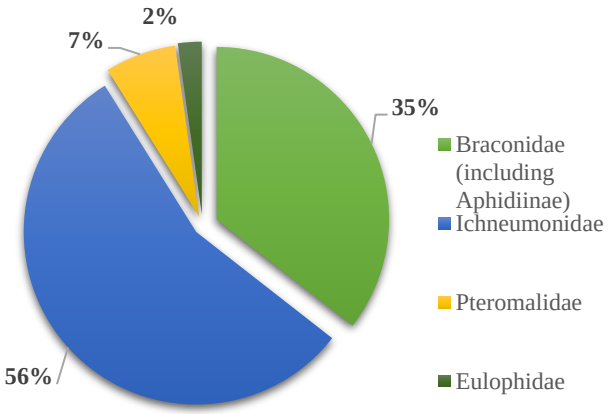
Table 5. Predatory entomofauna on winter oilseed rape, registered in the region of the Plovdiv in 2022

Order	**Family**	**Species**
Coleoptera	Coccinellidae	*Coccinella septempunctata* Linnaeus, 1758
		Hippodamia variegata Goeze, 1777
		Harmonia axyridis Pallas, 1773
		Propylea quatuordecimpunctata (Linnaeus, 1758)
		Adalia bipunctata (Linnaeus, 1758)
	Cantharidae	*Rhagonycha fulva* (Scopoli, 1763)
Hemiptera	Miridae	*Deraeocoris ribauti* Wagner, 1943
	Nabidae	*Nabis* sp.
Neuroptera	Chrysopidae	*Chrysoperla carnea* (Stephens, 1836)
		Chrysopa perla (Linnaeus, 1758)
Diptera	Syrphidae	*Scaeva pyrastri* (Linnaeus, 1758)
		Episyrphus balteatus (De Geer, 1776)
		Sphaerophoria sp.
	Tachinidae	*Ectophasia crassipennis* (Fabricius, 1794)

The parasitoid entomofauna was recorded using the D-VAC sampling

method. Species from 4 families were registered, with the family Ichneumonidae taking a dominant place (Fig. 4).

Figure 4. Percentage ratio of the main families of Hymenoptera parasitoids on winter oilseed rape in the region of the city of Plovdiv in 2022



Current studies show that, globally, insect pests have a greater role as agents of biotic stress in winter oilseed rape than diseases. Our studies on the species composition of the pest entomofauna in the agrocenosis of winter oilseed rape confirm the presence in the greatest population density of the economically important pests for the whole of Europe – pollen beetle, flea beetles, weevils, brassica pod midge, and cabbage fly.

Until recently, neonicotinoids were the main group of PPPs effectively controlling canola pests. Their ban in Europe made pyrethroids the only group of conventional insecticides approved for use against pests of this crop. The emergence of resistance in the populations of the main economically important pests, as well as the negative effect on the populations of the beneficial entomofauna, necessitates the search for alternative solutions aimed at

effective pest control and minimal risk to the agro-ecosystem.

Researching and developing new options for integrated pest management, environmentally friendly approaches and reducing reliance on synthetic insecticides is an important step towards sustainably maintaining populations of both pests and their natural enemies. The challenge is, on the one hand, to test and propose new non-conventional solutions for the control of pollen beetle and brassica pod midge, thus reducing or completely eliminating the use of highly toxic total pesticides such as synthetic pyrethroids, and on the other hand, to proposed a concept for the conservation of beneficial entomofauna, a provider of key ecosystem services in the rapeseed agrocenosis.

Since the discovery of their biocidal effect and their use as plant protection products, potassium salts of fatty acids have been reported to have very low toxicity to humans and are considered environmentally safe relatively selective pesticides.

Considering the mechanism of their action, it is understandable why their application is mainly aimed at insects with a soft body, such as aphids, whiteflies, mealybugs, etc., which are more susceptible to the effect of contact with them. However, more and more research is directed towards exploring the possibilities of their application also against beetles and other insects with a harder exoskeleton (Price et al., 2023).

3.2. Testing of the efficacy of eco-friendly insecticides fot the control of pollen beetle *Brassicogethes aeneus* (Fabricius, 1775)

The pollen beetle is a serious pest of oilseed rape in Europe, attacking the crop during flowering and seed formation and is capable of causing serious yield damage. Its resistance to certain insecticides, based on an emerging trend to develop effective pest control strategies that minimize impact on beneficial entomofauna, suggests a great need for effective and environmentally sustainable techniques to control populations of this pest.

Studies conducted in 2019-2021 show that potassium salts of aliphatic carboxylic acids exhibit significant efficacy against pollen beetle adults and could be an alternative to conventional insecticides (pyrethroids) and an environmentally friendly agent suitable for integrated pest management systems in winter oilseed rape.

- **2019 – location in the area of Zhelyazno village, Plovdiv region (GPS 42.223901 N; 24.772884 E)**

Immediately before the first treatment, a homogeneous spread of the pest observed in all plots, almost the same population density was recorded in all variants (table 6).

Table 6. Average number of adults of the pollen beetle on 50 main shoots, recorded in the experiment in the village of Zhelyazno, Plovdiv region in April 2019

Assessment number	**Variants**				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
Assessment before the treatment	19 ± 4.55	19.5 ± 2.38	19 ± 3.46	20 ± 2.83	20 ± 2.94
1st assessment	24 ± 5.10	7.5 ± 1.73	1.5 ± 0.58	2.5 ± 1.00	0.25 ± 0.50
2nd assessment	28.5 ± 7.33	6.25 ± 5.25	1 ± 0.82	0.75 ± 0.96	0 ± 0.00
3rd assessment	31.25 ± 5.56	11.5 ± 2.08	0.5 ± 1.00	5 ± 2.71	0 ± 0.00
4th assessment	36 ± 6.14	27 ± 2.65	13 ± 5.12	16 ± 4.08	9 ± 2.22

* In all tables in this section, potassium salts mean potassium salts of aliphatic carboxylic acids

At the first assessment (3 days after the first treatment), an increase in the number of the pest was noticed in the untreated control, in contrast to the other variants.

The most significant difference is between the control and the plots treated with Mavrik 2F, where efficiency reaches 98.8% (Table 7). The effectiveness

in variants treated with the higher dose of potassium salts (5 l/ha) and Decis 100 EC is around 92% (table 7).

Table 7. Efficacy (%) of eco-friendly insecticides in the control of pollen beetle *Brassicogethes aeneus* in the village of Zhelyazno, Plovdiv region in April 2019

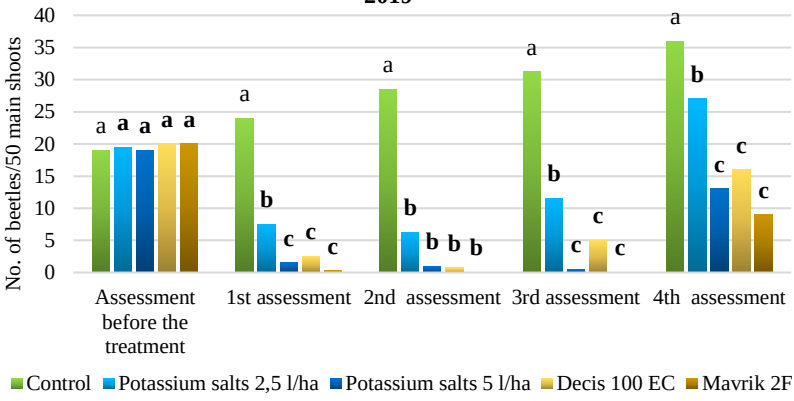
Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	0	69.6	92.7	92.4	98.8
2nd assessment	0	78.6	95.9	97.6	100
3rd assessment	0	64.1	98.1	85.3	100
4th assessment	0	27.3	56.4	58.7	69.5

In the second assessment (7 days after the first treatment) (table 7), an increase in efficacy was observed in all variants, and in the variant with the reference product Mavrik 2F it reached 100%. The variants treated with potassium salts at the higher dose and deltamethrin again had similar values of registered efficacy. On the same day, the variants with potassium salts of fatty acids were treated for the second time.

In the third assessment (Table 7), the efficacy in the variants treated with potassium salts in the low dose and deltamethrin decreases. In the variant treated with potassium salts at a dose of 5 l/ha, the efficiency increased by 2.2%. In the plots with a reference product based on tau-fluvalinate, the efficacy remained 100% - no live adults of the pollen beetle were recorded (Table 7).

In the final assessment (Table 7), the last three variants, treated respectively with potassium salts in the higher dose, deltamethrin and tau-fluvalinate, kept the significant differences compared to the control and the variant sprayed with potassium salts in the lower dose (Fig. 5).

Figure 5. Average population density of pollen beetle in the field experiment in the village of Zhelyazno, Plovdiv region in 2019



Statistical analysis of the data showed that the most strongly demonstrated differences between the variants treated with the higher dose of potassium salts and the control were observed in the assessments after the first and second treatments (Fig. 5).

The analysis of the quantitative and qualitative characteristics of the yield show that in the variants treated with potassium salts or reference products, their values are higher compared to the control. In the variant with potassium salts at a dose of 5 l/ha, the results were 5% better than the control, and at a dose of 2 l/ha by 2.7%.

- **2020 – location in the land of the village of Trastenik, Ruse region (GPS 43.708899 N; 25.946042 E)**

The data on the population density of the pest on the day of the first treatment with the potassium salts of aliphatic carboxylic acids and the reference products show that there are no significant differences in the number of registered beetles between the variants at that time (Table 8).

Table 8. Average number of adults of the pollen beetle on 50 shoots recorded in the experiment in the village of Trastenik, Ruse region n April 2020

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	20 ± 6.48	18 ± 8.29	14 ± 5.35	21.75 ± 4.57	19 ± 7.53
2nd assessment	23.5 ± 5.69	6.75 ± 1.89	2.5 ± 1.29	0 ± 0	4 ± 1.83
3rd assessment	25 ± 5.48	3.75 ± 0.96	0	0	0
4th assessment	28.25±5.56	10.5 ± 2.38	0	5.8 ± 2.06	2.5 ± 1.91
1st assessment	27.3 ± 6.13	17.8 ± 3.69	5.3 ± 1.50	17.8 ± 2.99	10.3 ± 1.89

The first assessment, carried out two days after treatment, shows that the two products containing potassium salts of aliphatic carboxylic acids have a very good insecticidal effect. Treatment at a dose of 2.5 l/ha resulted in a threefold reduction in the reported number of live beetles compared to the control, while at the higher dose the reduction was sevenfold. The efficacy is 70.9% and 88.1%, respectively (Table 9).

In the second assessment, seven days after the first treatment and coinciding with the second treatment, the number of live beetles in the variant with the low dose of potassium salts was 6 times less compared to the control, and in the variant treated with a dose of 5 l/ha – no live beetles were registered

(Table 8). The efficacy in the variant with potassium salts in the high dose is 100%, the same was recorded for the reference products (table 9).

Three days after the second treatment (Table 9), a decrease in the efficacy of most products was observed, but with the potassium salts in a dose of 5 l/ha, the efficacy was 100%, higher than the reference products.

Table 9. Efficacy (%) of eco-friendly insecticides in the control of pollen beetle *Brassicogethes aeneus* in the village of Trastenik, Ruse region in April 2020

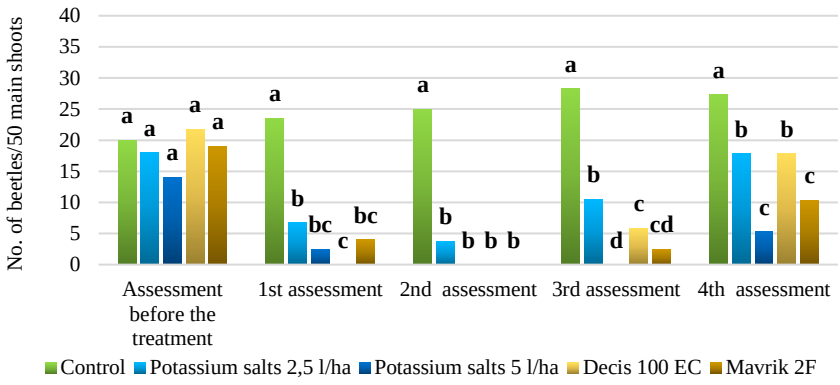
Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	0	70.9	88.1	100.0	82.8
2nd assessment	0	84.8	100	100	100
3rd assessment	0	62.3	100	80.7	91.0

At the fourth assessment, seven days after the second treatment (Table 8) of the experimental plots with potassium salts at a dose of 2.5 l/ha, the reduction in the number of living beetles was almost two-fold, the efficacy was 34.0%, respectively, and at the higher dose of 5 l/ha and the efficacy is 78.5%, it remains higher compared to the two reference products (Table 9).

The analysis of the data from the experiment conducted in the village of Trastenik in 2020 also shows that the largest and statistically proven differences are between the variants with potassium salts at a dose of 5 l/ha and the control in the assessments after the first and second treatment (Fig. 6).

Quantitative yield indicators show marginally higher yields in the variant treated with potassium salts of fatty acids at a dose of 5 l/ha.

Figure 6. Average population density of pollen beetle in the field experiment in the village of Trastenik, Ruse region in 2020



- **2020 – location in the area of the village of Trud, Plovdiv region (GPS 42.213480 N; 25.799381 E)**

The experiment in the village of Trud, Plovdiv region in 2020 was also started with a relatively leveled density of the pest in the test plots of the variants (Table 10).

One day after the first treatment, the two products containing potassium salts showed a very good insecticidal effect. Treatment at a dose of 2.5 l/ha showed almost twofold and the higher dose fourfold reduction in the number of beetles compared to the control, the efficacy was over 50%. In reference products, the efficacy reaches 100% (Table 11).

In the second assessment, when a second treatment of the variants with potassium salts was also done, the efficacy was highest in the variant treated with the higher dose of the tested product – 96.1%. Three days after the second treatment, a decrease in the efficacy of all products was observed, but the highest (54.3%) was preserved in the variant with potassium salts at a dose of 5 l/ha (Table 11).

Table 10. Average number of adults of the pollen beetle on 50 shoots, recorded in the experiment in the village of Trud, Plovdiv region in April 2020

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	11.75 ± 1.9	15.25 ± 10.3	10 ± 2.2	10.5 ± 5.8	17 ± 5.5
2nd assessment	11.75 ± 4	7 ± 4.8	3 ± 2.2	0	1 ± 2
3rd assessment	7.5 ± 7.9	3 ± 2.9	0.25 ± 0.5	0.75 ± 0.5	1.3 ± 1.7
4th assessment	7 ± 6.4	4 ± 5.7	4 ± 2.4	4 ± 6.7	5 ± 6.4
1st assessment	11.8 ± 8.1	5 ± 2.4	2.5 ± 3.7	1.8 ± 1.7	1.8 ± 2.1

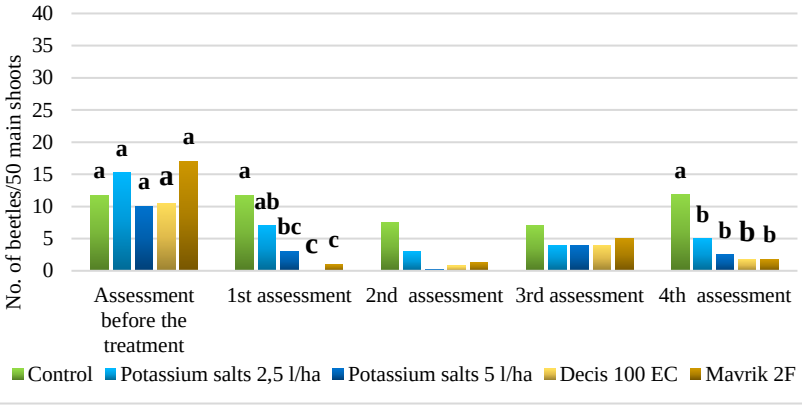
At last assessment, the efficacy of potassium salts applied at the higher rate of 5 l/ha was 75%, 14.7% lower than tau-fluvalinate.

Таблица 11. Efficacy (%) of eco-friendly insecticides in the control of pollen beetle *Brassicogethes aeneus* in the village of Trud, Plovdiv region in April 2020

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	0	54.1	70	100	94.1
2nd assessment	0	69.2	96.1	88.8	86.2
3rd assessment	0	26	54.3	29.5	46.2
4th assessment	0	67.2	75	83.3	89.7

Population pest densities were generally lower in this experiment and differences in the number of pest adults found during two of the observations were not statistically significant (Fig. 7).

Figure 7. Average population density of pollen beetle in the field experiment in the village of Trud, Plovdiv region in 2020



However, even at the first assessment after treatment, it can be seen that the variant treated with potassium salts in the high dose differs sharply from the control and falls into the same group with the two reference products.

At a dose of 2.5 l/h and 5 l/ha of potassium salts of fatty acids, the yield increases by about 4% and 5%, respectively.

- **2021 – location in the region of Plovdiv (GPS 42.205723 N; 24.714811 E)**

The experiment carried out in the Plovdiv region in 2021 confirmed the results of the good effect of potassium salts against the adults of the pollen beetle - the population density of the pest decreased from two to four times after the first treatment and many times more after the second one (Table 12).

The efficacy reaches up to 91.8% when treated with potassium salts in the low dose and up to 100% when they are applied in the higher dose of 5 l/ha (Table 13). In the variants with the reference products, it varies from 82.2 to 100%.

Table 12. Average number of adults of the pollen beetle on 50 shoots, recorded in the experiment in the city of Plovdiv in April 2021

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st Assessment	16.25 ± 5.7	24 ± 8	16 ± 8.1	17 ± 10.4	24 ± 13.4
2nd assessment	17.5 ± 5.3	13.5 ± 13.1	3.5 ± 2.4	3.75 ± 2.6	3 ± 2.9
3rd assessment	27.75 ± 4.9	11.25 ± 6.5	0	0	0
4th assessment	29 ± 4.3	4 ± 2.5	0	1 ± 0.1	0

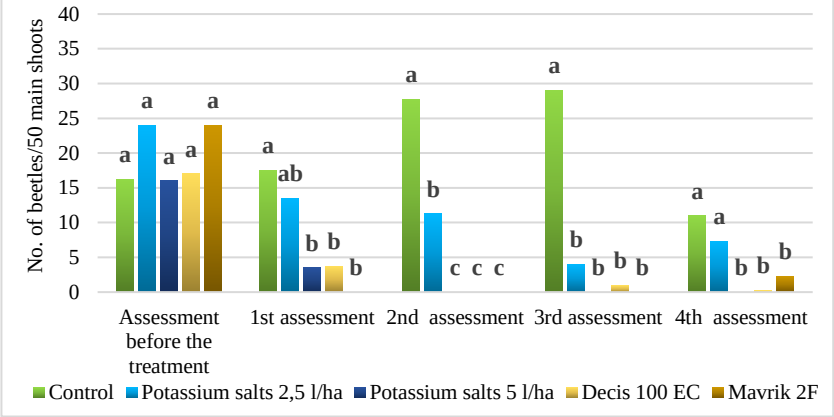
Table 13. Efficacy (%) of eco-friendly insecticides in the control of pollen beetle *Brassicogethes aeneus* in the region of Plovdiv in 2021

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	0	47.8	79.7	82.2	88.4
2nd assessment	0	72.6	100	100	100
3rd assessment	0	91.8	100	97.5	100
4th assessment	0	55.4	100	97.8	86.2

The statistical analysis of the data showed that the differences between the control and the variant with the high dose of potassium salts of fatty acids were greatest at the second and third readings (Fig. 8).

The productivity of the crop in this experiment was hardly affected after the application of the potassium salts at a dose of 2.5 l/ha, while at 5 l/ha there was an increase in yield by about 4% compared to the untreated control.

Figure 8. Average population density of pollen beetle in the field experiment in the region of Plovdiv in 2021



In conclusion, we can say that the results of the experiments carried out in four locations in three calendar years that the efficacy when applying the potassium salts in the higher dose of 5 l/ha varies from 70 to 92.7% in the first assessment (1-3 days after treatment), from 95.9 to 100% at the second assessment (7 days after treatment), from 54.3 to 100% at the third assessment (10-11 days after the first and 3-4 days after the second treatment) and from 56.4 to 100 % at the last assessment (14-15 days after the first and 7-8 days after the second treatment). Compared to the reference products (Decis 100EK and Mavrik 2F), the results of treatment with these salts are similar or better. At the lower application rate of 2.5 l/ha, efficacy varied from 26% to 91.8% in the different years and locations where the trials were conducted.

In terms of yields, all variants in almost all locations show higher results compared to the control, with the exception of the experiment conducted in the region of Plovdiv in 2020, where the highest yield was reported for the variant treated with Decis 100EK. In all other locations, the variant treated with salts

of fatty acids in a dose of 5 l/ha showed the best results.

3.3. Testing of the efficacy of eco-friendly insecticides for the control of brassica pod midge *Dasineura brassicae* (Winnertz, 1853)

The brassica pod midge, *Dasineura brassicae*, is another major pest in Europe that damages the generative organs of canola and can cause serious damage to crop productivity. The use of insecticides during canola flowering, when the pest begin to fly, often conflicts with the protection of pollinators and other beneficial insects.

Studies conducted in 2020-2022 show that potassium salts of aliphatic carboxylic acids have potential as an insecticide to be used to control populations of this pest.

- **2020 – location in the area of the village of Vojvodinovo, Plovdiv region (GPS 42.213480 N; 25.799381 E)**

The number of damaged pods recorded before the first treatment was without significant differences between the control and the variants, i.e. the experiment was set at the same initial degree of infestation by the pod midge (Table 14, Figure 9).

Table 14. Average number of damaged pods by larvae of the pod midge, recorded on 25 shoots in the experiment in the village of Vojvodinovo, Plovdiv region in May 2020

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
Assessment before treatment	5.25 ± 2.22	4.5 ± 1.73	5.5 ± 1.73	5.0 ± 2.94	4.75 ± 1.71
1st assessment	2.25 ± 0.5	1.5 ± 0.58	1.0 ± 0.82	0.75 ± 0.5	0.5 ± 0.58
2nd assessment	10.5 ± 2.65	10.5 ± 2.89	5.75 ± 1.71	5.5 ± 3.11	5.5 ± 3.42

The experiment conducted in the area of the village of Vojvodinovo, Plovdiv region shows that the degree of damage by pod midge larvae after the first treatment is almost twice lower in the treated variants compared to the control (Table 14).

The efficacy reaches 55.6% when the potassium salts of fatty acids are applied in a dose of 5 l/ha, which is very close to the values of reference products, respectively 66.7% for deltamethrin and 77.7% for taufluvalinate (Table 15).

The trend is maintained in the second assessment as well. At the higher dose of potassium salts, 5 l/ha, the damaged pods were twice less than in the control (Table 14), and the efficacy was 45.24%, close to that of the reference products, Decis 100 EC and Mavrik 2F, in which the efficacy is 47.62% (Table 15).

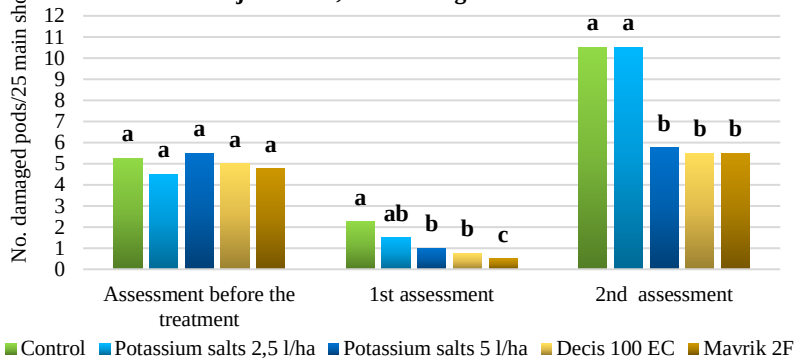
Table. Efficacy (%) of eco-friendly insecticides in the control of brassica pod midge in the village of Vojvodinovo, Plovdiv region in May 2020

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	0	33.3	55.6	66.7	77.7
2nd assessment	0	0	45.24	47.62	47.62

The analysis of the data from the experiment in the village of Vojvodinovo show that there are statistically proven differences in the degree of infestation by brassica pod midge larvae only between the variant treated with the higher dose of potassium salts of aliphatic carboxylic acids and the control, as after the first, as well as after the second treatment (Fig. 9).

In the variant with application of the product at a lower dose, the number of damaged pods was also lower, but the difference with the control was not statistically proven.

Figure 9. Average degree of damage by brassica pod midge larvae on oilseed rape in the field experiment in the village of Vojvodinovo, Plovdiv region in 2020



The analysis of the quantitative and qualitative characteristics of the yield in this experiment show that the application of potassium salts at a dose of 2.5 l/ha increases the yield by 2.1% compared to the control, and at a dose of 5 l/ha the increase is by 3.9 %. The increase in yield in the plots treated with deltamethrin and tau-fluvalinate was 9.9% and 10.6%, respectively.

- **2021 – location in the region of Plovdiv (GPS 42.205128N; 24.715333E)**

In the study, conducted in the second location in the region of the city of Plovdiv in 2021, a reduction in the degree of infestation by larvae of the pod beetle was observed already at the first assessment (Table 16).

Table 16. Average number of pods damaged by larvae, recorded on 25 shoots in the experiment in the city of Plovdiv in May 2021

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
Assessment before treatment	3.0 ± 1.41	4.25 ± 0.96	3.5 ± 2.08	4.0 ± 2.71	4.0 ± 0.82
1st assessment	1.75 ± 0.96	1.5 ± 1.00	0.5 ± 1	0.25 ± 0.5	0.25 ± 0.5
2nd assessment	6.5 ± 2.08	5.0 ± 2.58	2.5 ± 1.00	3.0 ± 2.16	2.5 ± 1.29

The efficacy in the variant treated with low doses of potassium salts is small (up to 23.08%), while in the variant treated with the higher dose, its values approach the reference products - 71.4% (Table 17) . The registered efficacy in this experiment is the highest for the two reference products (85.7%), although in these variants its values do not reach 100%.

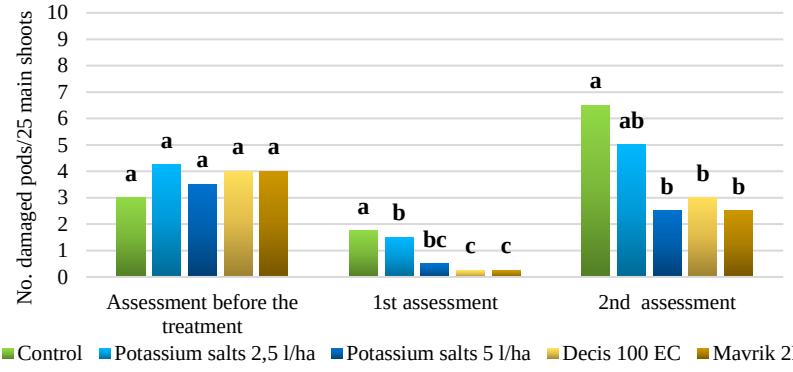
Table 17. Efficacy (%) of eco-friendly insecticides in the control of brassica pod midge in the experiment in the region of Plovdiv in 2021

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	0	14.3	71.4	85.7	85.7
2nd assessment	0	23.08	61.54	53.85	61.54

At the second assessment the number of damaged pods in the variant with the low dose of potassium salts was close to the values recorded in the control (Table 16). In the variant treated with the high dose of potassium salts, the highest efficacy was recorded - 61.54%, matching the efficacy of the reference product Mavrik 2 F (Table 17).

Statistically analyzing the results of the experiment in the region of Plovdiv, we can say that in three of the treated variants (potassium salts 5 l/ha and the two reference products) the degree of infestation is lower compared to the control and this difference is statistically proven (Fig. 10).

Figure 10. Average degree of damage by brassica pod midge larvae on oilseed rape in the field experiment in the region of Plovdiv in 2021



- **2022 – location in the area of the village of Koprinka, Srata Zagora region (GPS 42.205128N; 24.715333E)**

In the experiment conducted in the village of Koprinka, Stara Zagora region in 2022, the very first assessment found statistically proven differences in the number of infested pods in the treated variants and the control (Table 18 and Fig. 11). In the variants with potassium salts, the efficacy is 100% at both treatment doses 2.5 l/ha and 5 l/ha (Table 19). For comparison, the efficacy of both reference products deltamethrin and tau-fluvalinate is lower - 75%.

In the second assessment, it was found that in the experimental plots treated with potassium salts at a dose of 2.5 l/ha, the efficacy was 62.1%, and at the higher dose of 5 l/ha, the number of damaged pods was significantly

more low compared to the control,, respectively, the efficacy is 89.7% (Table 19). The reference products were registered with lower efficacy, respectively 51.7% and 62.1%.

Table 18. Average number of damaged pods by larvae of the brassica pod midge, recorded on 25 shoots in the experiment in the village of Koprinka, Stara Zagora region in May - June 2022

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
Assessment before treatment	4.0 ± 1.63	6.0 ± 1.41	3.25 ± 0.5	5.0 ± 0.81	4.25 ± 2.62
1st assessment	2 ± 0.82	0	0	0.5 ± 0.58	0.5 ± 0.85
2nd assessment	7.25 ± 1.26	2.75 ± -0.96	0.75 ± 0.5	3.5 ± 2.08	2.75 ± 1.26

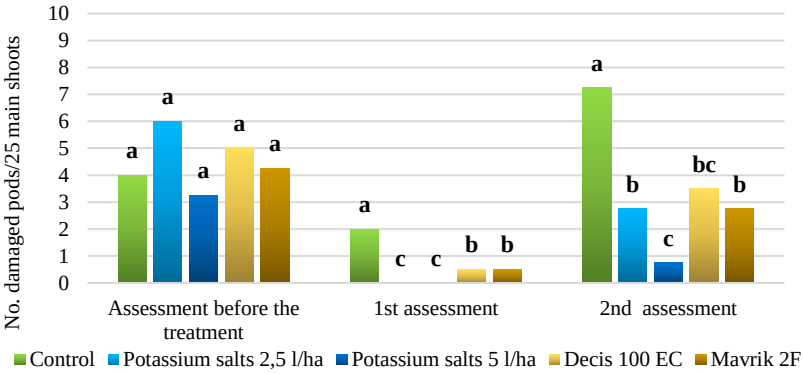
Table 19. Efficacy (%) of eco-friendly insecticides in the control of brassica pod midge in the village of Koprinka, Stara Zagora region in May - June 2022

Assessment number	Variants				
	Control	Potassium salts* - 2,5 l/ha	Potassium salts* - 5 l/ha	Decis 100 EC	Mavrik 2F
1st assessment	0	100	100	75	75
2nd assessment	0	62.1	89.7	51.7	62,1

The analysis of the results presents the statistical significance of the differences in the degree of infestation by the pod midge between the variants in the experiment in the region of the village of Koprinka (Fig. 11).

In this experiment, the rate of infestation was significantly lower in both variants with potassium salts and their difference with the control was statistically significant.

Figure 11. Average degree of damage by brassica pod midge larvae on oilseed rape in the field experiment in the village of Koprinka, Plovdiv region in 2022



In the variant with a dose of the potassium salts of fatty acids 2.5 l/ha, the yield increase was only 0.6%, while with a dose of 5 l/ha the increase was about 4.87% compared to the untreated control. The increase in yield in variants with reference products, deltamethrin and tau-fluvalinate, was 6.12% and 4.19% higher than the control, respectively.

In conclusion, we could say that the tested potassium salts of fatty acids, applied at the higher dose of 5 l/ha, show an efficacy close to the reference products against brassica pod midge. At the first assessment (5th-6th day after treatment) the efficacy varied from 55.6 to 100% in different locations and years, and at the second assessment (15th-16th day after first treatment) it was from 45.24 to 89.7 %. At the lower dose, the efficacy was between 14.3% and 100%. In 2022, during the experiment in the village of Koprinka, they showed even higher efficacy compared to Decis 100EK and Marvik 2F. In terms of harvested production, all products showed an increase in yields compared to the untreated control.

3.4. Effect of flowering plant species on the beneficial entomofauna of winter oilseed rape

As already stated, the problem of resistance of economically important canola pests to pyrethroids and the ban in Europe of neonicotinoids creates the need to study and propose alternative strategies to control populations of phytophagous insects, with a particular challenge being those that multiply and cause damage during flowering, when the agrocenosis is intensively visited by pollinators and other beneficial insects.

Spatial diversification of agroecosystems represents a viable strategy for improving biological pest control and promoting biodiversity. The presence of flowering strips on the periphery of the crop or in it does not always have the expected beneficial effect, one of the reasons being the potential incompatibility between natural enemies and flowering plant species.

The aim of this study is to develop flower strips of flowering plant species specific to Bulgaria, which on the one hand attract, enhance and maintain populations of important ecosystem service providers, with a main focus on pollinators and natural enemies of canola pests, and on the other hand, to minimize the negative effects of the culture treatments carried out, providing alternative habitats for beneficial insects. The study follows a comprehensive approach, including the selection of different flowering plant species that are easy to sow and grow under field conditions, evaluating their attractiveness to visitors for their flowers and providing a list of species optimized for local conditions.

Eighteen of the selected 21 plant species, sown according to a scheme in a winter rapeseed crop, specially created for the purposes of the field experiment in the Plovdiv region in 2021-2022, are developing successfully. Three plant species did not germinate and were excluded from the analysis of the results. These are: medicinal hyssop (*Hyssopus officinalis*), mountain arnica (*Arnica montana*) and purple viper's-bugloss (*Echium plantagneum*). In

2022-2023, for the same reason, the following 4 plant species were excluded from the experiment: common mallow, dandelion, cumin and mountain arnica.

The reported beneficial entomofauna found on flowering plants is divided into two groups – pollinators (honeybees, bumblebees and syrphid flies) (Figs. 12 and 14) and flower-visiting entomophagous insects (mostly predators) (Fig. 13 and 15).

During the growing season of 2021-2022, phacelia (*Phacelia tanacetifolia*) attracted the largest number of pollinators - an average number of 3.45 during the flowering period, followed by fennel (*Foeniculum vulgare*) - 1.65, coriander (*Coriandrum sativum*) and borage (*Borago officinalis*) – 1.5 (Fig. 12). The fewest pollinators are attracted to cumin, chamomile, buckwheat and flax - on average number less than 0.5 pollinators for the entire vegetation.

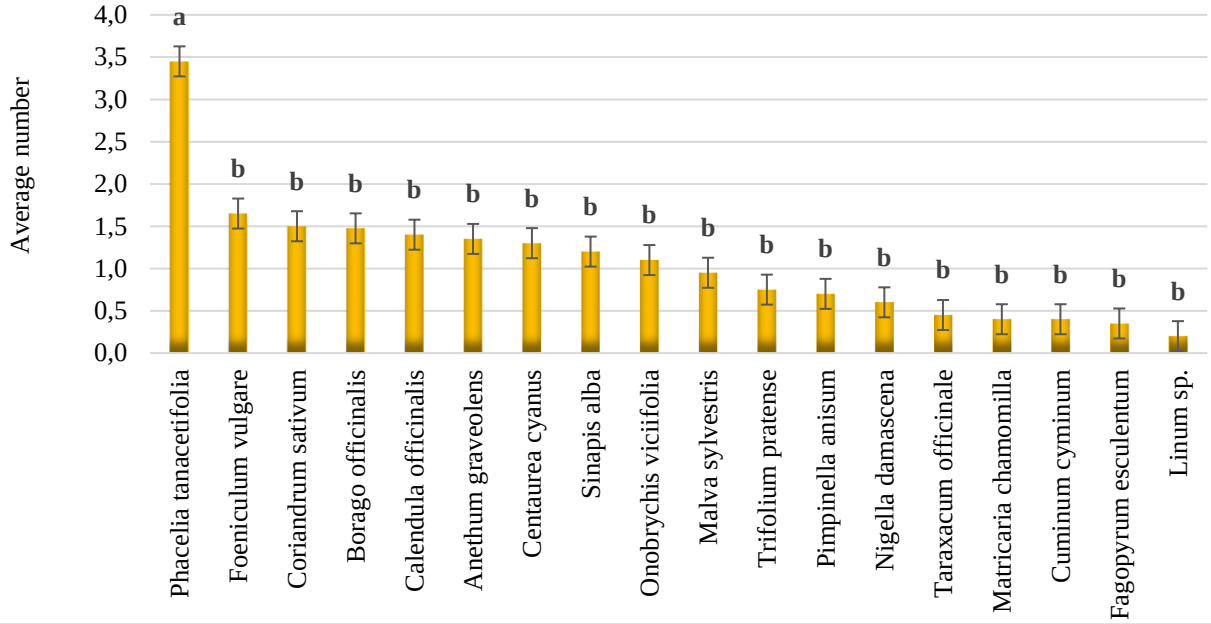
One-way ANOVA of the results and Tukey HDS (Honestly Significant Difference) test at significance level a = 0.05 showed statistically significant differences in the number of pollinators recorded in the different flowering species ($F=4.58$, $p=0.00<0.05$).

The analysis shows that the studied plant species are divided into two groups (marked in Fig. 12 with a different letter) depending on their ability to attract pollinators. Phacelia significantly differs from the other flowering plants included in the test.

The group of entomophagous insects (predominantly predatory species) visiting the flowering plants showed the greatest preference for phacelia (*Phacelia tancetifolia*), clover (*Trifolium pratense*) and common sainfoin (*Onobrychus vicifolia*) (Fig. 13). In all three plant species, the average number of predatory insects attracted during the vegetation of 2022 is over 1. The average number of attracted predators is over 0.5 in coriander, cumin, fennel and anise.

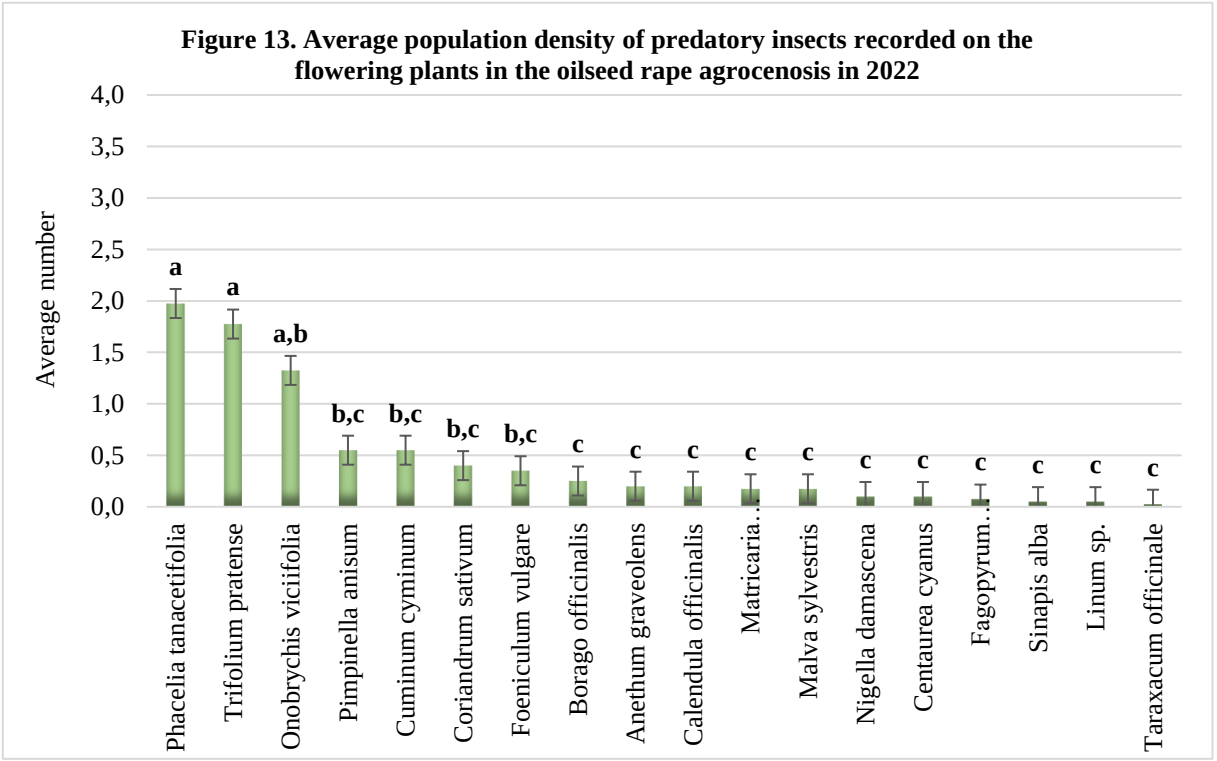
The lowest number of predatory insects (less than 5 for the entire vegetation period) attracted the following species: dandelion (*Taraxacum officinale*), flax (*Linum* sp.) and white mustard (*Sinapis alba*) - on average less than 0.05 number of predatory insects for the entire vegetation period (Fig. 13).

Figure 12. Average population density of pollinators attracted to flowering plants in oilseed rape agrocenosis in 2022



***ANOVA, Tukey's HD (Different letters indicate statistically significant differences, according to Tukey's test (p<0.05)**

Figure 13. Average population density of predatory insects recorded on the flowering plants in the oilseed rape agrocenosis in 2022



The results of the analysis of variance showed that the established differences between flowering plant species and their ability to attract predators were statistically proven ($F=7.608$, $p=0.00<0.05$). The tested plants are divided into 3 groups (Fig. 13), with the phacelia and clover being the most significantly distinguished from the others.

In 2022-2023, the experiment was carried out according to the same scheme, but with the exclusion of 4 of the species, which means that 17 developed successfully.

The results in the second experimental year to some extent repeat those obtained in the previous year, with this difference that, in general, the number of recorded insects (mainly pollinators) visiting the flowers is higher. The highest number of pollinators was again attracted by phacelia (25.28 on average), followed by *Echium plantagineum* (14.98), buckwheat (9.13), borage (7.38), white mustard (7 .30) and coriander (3.50). Phacelia, borago and coriander confirm their role as species with a good ability to attract pollinators (Fig. 14).

The one-factor analysis of variance proves the statistical significance of the established differences in the number of observed pollinators in the different flowering species ($F=20.17$, $p=0.00<0.05$). The significance test of the differences between the means divided the flowering plant species into 4 groups (Fig. 14).

Regarding natural enemies (predators), a difference is observed compared to 2022 (Fig. 15). The largest number of predatory insects attracted fennel (*Anethum graveolens*), white mustard (*Sinapis alba*) and coriander (*Coriandrum sativum*) – the average number of individuals recorded on these plants was 3.3, 2.9 and 2.65, respectively. Borago and phacelia are also included in the group of species preferred by predators (Fig. 15).

Figure 14. Average population density of pollinators attracted to flowering plants in oilseed rape agrocenosis in 2023

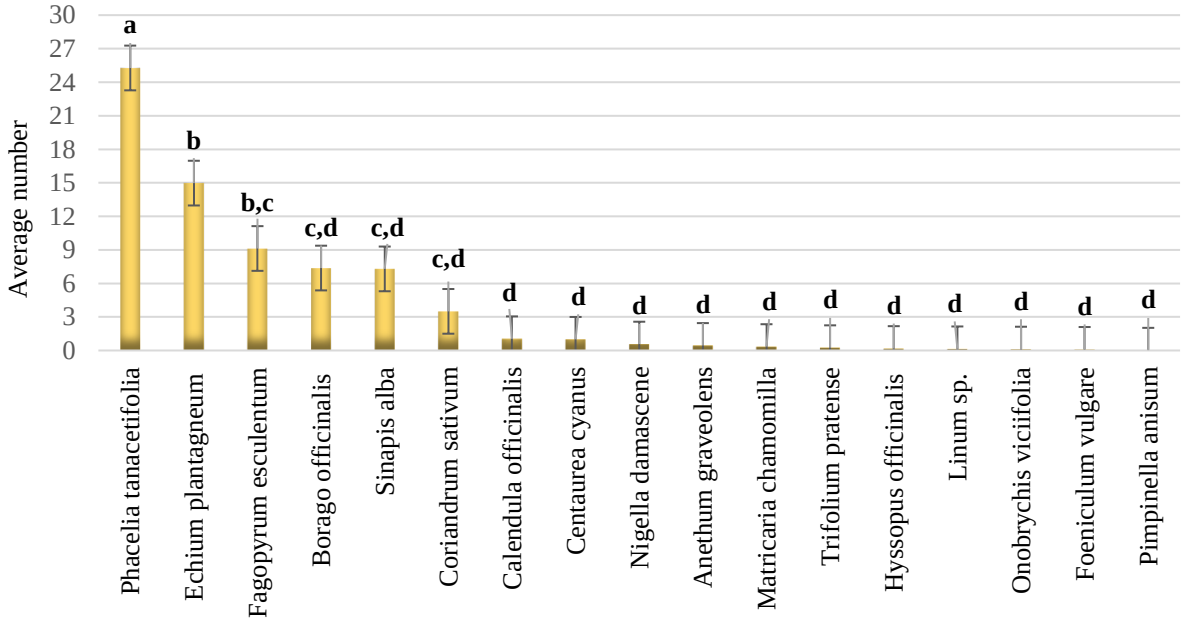
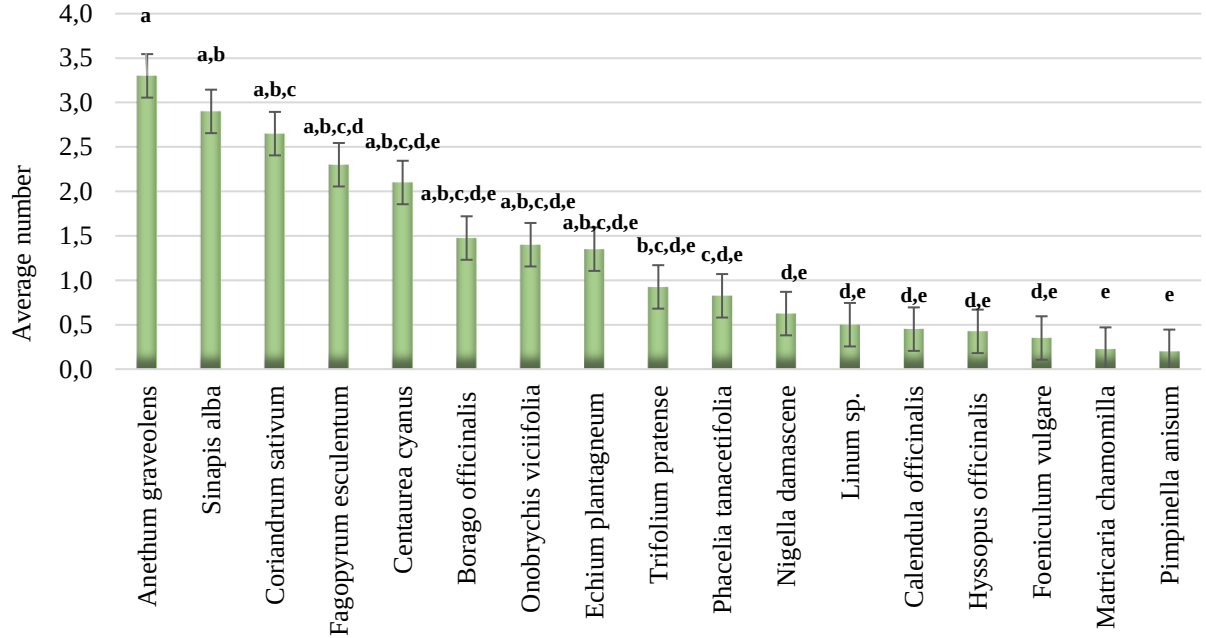


Figure 15. Average population density of predatory insects recorded on the flowering plants in the oilseed rape agrocenosis in 2023



The data analysis shows a statistically significant difference in the ability of different flowering plants to attract predators, forming 5 groups whose average values have statistically proven differences (F=6.23, p=0.00<0, 05) (fig. 15).

Analysis of the entire complex of flower-visiting insects shows that its diversity is different in different flowering plants. In 2022, several types of plants, borage, fennel, phacelia and common sainfoin, attracted insects from all groups observed, and coriander, fennel and red clover attracted more than two groups of beneficial insects (Table 20).

Table 20. List of flowering plant species preferred by most pollinators and predators recorded in 2022

Plant species*	Honey bees	Syrphid flies	Predatory ladybirds	Predatory bugs	Lacewings
A.graveolens	+	+	+	+	+
B. officinalis	+	+	+	+	+
C. sativum	+	+	+		
F. vulgare	+	+	+		
O. viciifolia	+	+	+	+	+
P.tanacetifolia	+	+	+	+	+
T.pratense	+	+	+		

*Plant species that attract insects from all groups of beneficial species are marked in orange.

The analysis of the data from 2023, representing the ability of different flowering plants to attract pollinators from more than one group, shows that four of the studied plant species are attractive to all groups of observed insects - borago, buckwheat, phacelia, and purple viper's-bugloss (table. 21).

Analyzing the species capable of attracting predatory insects from several families, we can say that 10 of the 17 observed species in 2023 are attractive to more than one group of predators subject to monitoring - predatory ladybirds, predatory bugs, lacewings and solder beetles (table 22).

Seven of the flowering plants are visited by almost all predator groups.

Table 21. List of flowering plant species preferred by most pollinators recorded in 2023

Plant species*	Syrphid flies	Honey bees	Bumblebees	Other Hymenoptera pollinators	Other Diptera pollinators	Lepidoptera
B.officinalis	+	+	+	+	+	+
E.plantagineum	+	+	+	+	+	+
F. esculentum	+	+	+	+	+	+
P. tanacetifolia	+	+	+	+	+	+
S. alba	+	+	+	-	+	+
C. cyanus	+	+	-	+	+	+
T.pratense	-	+	-	-	+	-

*Plant species that attract all pollinators are marked in orange.

Table 22. List of flowering plant species preferred by most predators recorded in 2021-2023

Plant species*	Predatory ladybirds	Predatory bugs	Lacewings	Solder beetls
C. sativum	+	+	+	+
A.graveolens	+	+	+	+
C. officinalis	+	+	-	+
S. alba	+	+	-	+
P. tanacetifolia	+	+	-	+
B. officinalis	+	+	-	+
E. plantagineum	+	-	-	+
C. cyanus	+	-	-	+
T. pratense	+	-	-	+
O. viciifolia	+	+	-	+

*Plant species that attract insects from all groups of predators are marked in green.

Summarizing the results of the experiment with flowering plant species carried out in 2021-2023 and the data analysis carried out, we can say that three plant species can be recommended for sowing flower strips in the agrocenosis of winter oilseed rape: phacelia (*Phacelia tanacetifolia*), borage (*Borago officinalis*) and coriander (*Coriandrum sativum*). These are plants that attract the most pollinators and predators, and from the widest range of taxonomic groups.

CONCLUSIONS

Based on the conducted studies and the analysis of the results, the following more important conclusions can be summarized:

1. Pest entomofauna in the agrocenosis of winter oilseed rape is characterized by a rich species composition, including insects from 5 orders, 11 families. The dominant group is species of the order Coleoptera, followed by Hemiptera.
2. Dominant species of phytophagous insects, multiplying in high density and infesting the generative organs of oilseed rape, are the pollen beetle *Brassicogethes aeneus* (Fabricius, 1775), the cabbage seed pod weevil *Ceutorhynchus obstrictus* (Marsham 1802) and the brassica pod midge *Dasineura brassicae* (Winnertz, 1853)
3. The potassium salts of aliphatic carboxylic acids (or fatty acids) with a carbon chain length of C_{14}-C_{20} exhibit a good insecticidal effect against adults of the pollen beetle and the brassica pod midge and are an effective alternative to pyrethroids.
4. Eifficacy of potassium salts of aliphatic carboxylic acids (C_{14}-C_{20}) tested against pollen beetle is dose-dependent, ranging from 26% to 91.8% at a dose of 2.5 l/ha and from 54.3 to 100% at a dose of 5 l/ha. Persistence lasts up to 15 days after the first treatment.
5. Efficacy of potassium salts of aliphatic carboxylic acids (C_{14}-C_{20}) tested against brassica pod midge ranged from 14.3% to 100% at a dose of 2.5 l/ha and from 45.24% to 100% at a dose of 5 l/ha huh. In one of the tests, the efficacy of the higher dose exceeded that of the reference products - deltamethrin and tau-fluvalinate.
6. Treatment with potassium salts of aliphatic carboxylic acids (C_{14}-C_{20}) does not negatively affect yield in oilseed rape, at a dose of 5 l/ha there is even a slight increase in yield.

7. Flowering strips in a rapeseed agrocenosis attract beneficial insects and enhance ecosystem services such as pollination and biological control.
8. The highest number of pollinators in both years of the study is recorded for phacelia (*Phacelia tanacetifolia*).
9. The highest number of predators in 2022 is registered for phacelia, and in 2023 - for fennel (*Anethum graveolens*).
10. Phacelia, borage (*Borago officinalis*), coriander (*Coriandrum sativum*), white mustard (*Sinapis alba*), fennel (*Anethum graveolens*), marigold (*Calendula officinalis*) and common sainfoin (*Onobrychis vicifolia*) are the plant species whose flowers attract pollinators and predators from the widest range of families.
11. Three flowering plant species can be recommended for sowing flower strips in agrocenosis of winter oilseed rape and these are: phacelia (*Phacelia tanacetifolia*), borage (*Borago officinalis*) and coriander (*Coriandrum sativum*).

DISSERTATION CONTRIBUTIONS REFERENCE

Original scientific contributions

- For the first time in Bulgaria, the effect of products containing potassium salts of aliphatic carboxylic acids (fatty acids) is being tested against the pollen beetle *Brassicogethes aeneus* and the brassica pod midge *Dasineura brassicae*.
- Potassium salts of aliphatic carboxylic acids (fatty acids) with a carbon chain length of C_{14}-C_{20} have been found to have good insecticidal activity against adults of pollen beetle and brassica pod midge and are an effective alternative to pyrethroids.
- Efficacy of potassium salts of aliphatic carboxylic acids (fatty acids) (C_{14}-C_{20}) against adults of pollen beetel and brassica pod midge is dose-dependent and could reach 100% at a dose of 5 l/ha, as the persistence lasts up to 15 days after treatment.
- For the first time in our country, it has been proven that the treatment with potassium salts of aliphatic carboxylic acids (fatty acids) (C_{14}-C_{20}) is completely safe for winter oilseed rape and does not negatively affect the yield of the crop, in some cases it increases it.
- For the first time in Bulgaria, the role of flowering plant species to increase ecosystem services, such as pollination and biological control, in the agrocenosis of winter oilseed rape is being studied.
- Phacelia (*Phacelia tancetifolia*), borage (*Borago officinalis*), coriander (*Coriandrum sativum*), white mustard (*Sinapis alba*), fennel (*Anethum graveolens*), calendula (*Calendula officinalis*) and common sainfoin (*Onobrychis vicifolia*) have been found to be the plant species whose flowers attract pollinators and predators from the widest range of families.
- Three plant species phacelia (*Phacelia tanacetifolia*), borago (*Borago*

officinalis) and coriander (*Coriandrum sativum*) can be recommended for sowing strips of flowering plant species in agrocenosis of winter oilseed rape.

Applied contributions

- Potassium salts of C_{14}-C_{20} aliphatic carboxylic acids (fatty acids) have been shown to be an effective alternative to pyrethroids and a resistance management tool.
- Potassium salts of aliphatic carboxylic acids (fatty acids) can find practical application in the development of IPM schemes in the production of winter oilseed rape. Long persistence makes them suitable for application in critical phases of the crop.
- The results of the studies on the role of flowering plant species in oilseed rape can find practical application in the sowing of strips of such plants, supporting the beneficial entomofauna in the agrocenosis.

DISSERTATION RELATED PUBLICATIONS

Ivanov, A., A. Harizanova, 2022. The use of ammonium sulphate has an adjuvant effect on the productivity of oilseed rape (Brassica napus L.). Scientific Papers. Series A. Agronomy 65 (2), 231-238.
https://agronomyjournal.usamv.ro/pdf/2022/issue_2/Art30.pdf

Ivanov, A., A. Harizanova. 2022. The effect of the carboxyl fatty acids as a biological control product against *Brassicogethes aeneus* F. on canola. Scientific Papers. Series A. Agronomy 65 (1), 379-385.
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