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Evaluation of the Effect of Various Biopesticides on the useful Arachno Entomofauna of the Apple Orchard in the Southeast of Kazakhstan

[1]I. I. Temreshev, [1]B. K. Kopzhasarov, [1]Z. B. Beknazarova, [1]A. E. Koigeldina and [2]A. S. Dzhanbatyrov

[1]*Limited Liability Company "Kazakh Scientific Research Institute of Plant Protection and Quarantine named after Zh. Zhiembayev", Kazakhstan*
[2]*Necommercial Joint Stock Company "Kazakh National Agrarian University", Kazakhstan*

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Corresponding Author:
Z.B. Beknazarova
Limited Liability Company "Kazakh Scientific Research Institute of Plant Protection and Quarantine named after Zh. Zhiembayev", Kazakhstan
Email: zibash_bek@mail.ru

Abstract: Currently, Kazakhstan is actively researching the greening of the protection of apple orchards from lepidopteran pests. In this regard, biological preparations of various origins were tested. The aim was to study their impact on useful non-target arachno entomofauna (entomophagous insects and pollinators). During the research, both classical methods used in entomology and plant protection, and original modifications were used. In the south-east of Kazakhstan, in the agrobiocenosis of an apple orchard, an assessment of the effects of biological preparations was carried out: Phytoverm ® K.E. (aversectin C, a natural mixture of four avermectins B1a, A1a, A2a, B2a, produced by *Streptomyces avermitilis* microorganisms), Greene Gold, 0.3% by weight (admiration), Entolek Planteco K ® (*Akanthomyces lecanii*), and Lepidocide ® S.K. (*Bacillus thuringiensis var. kurstaki*) on entomophagous insects of harmful lepidoptera and pollinators. The greatest decrease in the number of indicator species was observed in the variants with azadirachtin and avermectin. It is concluded that when these bioinsecticides are used together with entomophagous insects and pollinators, it is necessary to draw up and apply special step-by-step schemes with a time interval between the treatment with a biological product and the release of entomophagous insects or pollinators in summer. It is also desirable to study these drugs in more detail in terms of their prolonged action, not only on entomophagous insects and pollinators but also on soil-forming agents, in the conditions of Kazakhstan. Biological preparations based on *Bacillus thuringiensis* and *Akanthomyces lecanii* had almost no negative effect on the number of entomophagous insects and pollinators. When choosing biologics for use against harmful lepidoptera in apple orchards in the south-east of Kazakhstan, it is advisable to focus on these bioinsecticides as having a more sparing effect for non-target arachno entomofauna.

Keywords: Biological Preparation, Azadirachtin, Avermectin, *Akanthomyces lecanii*, *Bacillus thuringiensis*

Introduction

The orchard ecosystem is considered to be the most stable among the existing agrocenoses. It presents more than 400 species of harmful insects and ticks and about 1,000 species of related trophic entomophagous insects. Some of them, under favorable conditions, can significantly limit the number of pests (Evlakhova and Shvetsova, 1965; Statkevych and Drozda, 2020). In the untreated garden, the diversity of macroinvertebrate taxa was much higher (by 40% or more) than in the garden where chemical treatments are carried out, on which some taxa practically fall out. It was noted that insect species listed in the red book of the Republic of Kazakhstan and the red book of the Almaty region (*Phyllorgerius jacobsoni* Oshapin, 1913, *Zicrona caerulea* (Linnaeus, 1758), *Arma custos* (Fabricius, 1794), *Coranus subapterus* (De Geer, 1773), *Stethorus punctillum* Weise, 1885, *Callisthenes elegans* Kirsch, 1859), and particularly effective species of entomophagous insects (*Nabis ferus*

(Linnaeus, 1758), *Mastrus ridens* Horstmann, 2009, *Cubocephalus anatorius* (Gravenhorst, 1829) and some others), are found only in an uncultivated garden (Temreshev *et al*., 2017).

Currently, several methods are being used to control apple pests: Mechanical, agrotechnical, chemical, and biological. Mechanical and agrotechnical methods are rather preventive in nature. In the case of a strong spread of pests, it becomes necessary to use chemical means of protection-various pesticides from the class of pyrethroids, organophosphates, neonicotinoids, etc. However, the chemical method has numerous disadvantages that force one to seek a way out in the form of dose reduction, etc., (Walker *et al*., 2017; Román *et al*., 2022). An alternative to the chemical method of control is the use of biological preparations based on entomopathogenic organisms (viruses, bacteria, fungi, protozoa, and nematodes). Since some of them can affect various types of arthropods, including useful ones, it is necessary to conduct a preliminary assessment of their effect on the beneficial entomofauna of agrobiocenosis. In world practice, the assessment of the impact of widely used biological preparations on pollinators and entomophagous insects, and the possibility of their joint use in the production of organic products has been repeatedly highlighted in the works of researchers from around the world and continues to be relevant (Mahefarisoa *et al*., 2021; Presa-Parra *et al*., 2021; Erler *et al*., 2022). Currently, in Kazakhstan, the List of pesticides allowed for use on the territory of the Republic of Kazakhstan (State Inspection Committee in the Agro-industrial complex, 2020) includes 21 names of biological preparations, of which only 8 have been registered against pests of apple trees and green spaces. Of these, the impact assessment on the non-target fauna of entomophagous insects and pollinators was previously carried out only for the drug AkKobelek (Temreshev *et al*., 2018a; 2018b). The need for such studies is also justified, in addition to preserving the biodiversity of non-target species, by the commercial interests of agricultural producers. Currently, in Kazakhstan, most of them are forced to purchase entomophagous insects and pollinators (for example, bumblebees), for the production of organic products, abroad. Thus, the losses of beneficial insects due to the negative effects of untested biological products when they are used together turn into financial losses for farmers in the currency spent on their acquisition.

We chose four biological preparations for testing-Phytoverm ® K.E. (aversectin C, a natural mixture of four avermectins B1a, A1a, A2a, and B2a, produced by *Streptomyces avermitilis* microorganisms), Greene Gold, 0.3% by weight (admiration), Entolek Planteco K ® (*Akanthomyces lecanii*), and Lepidocide ® S.K. (*Bacillus thuringiensis var. kurstaki*) with various components as an active ingredient. Preparations based on these components are actively used in world practice for pest control. In addition, they are waste products of various organisms (*S. overdetails*-actinomycete; azadirachtin-a plant extract from the Neem tree, or Indian *Azadirachta indica*; *A. lecanii*-ascomycete fungus; *B. thuringiensis*-gram-positive, spore-forming soil bacterium). Based on the different origins of the components, one can assume a different nature of their impact on the non-target arachno entomofauna. This was the reason for the choice of these biological preparations.

The study aimed to study the effect of biological pesticides of various origins on useful non-target arachno entomofauna (entomophagous insects and pollinators).

Materials and Methods

Studies to assess the effect of biological insecticides on the non-target fauna of arthropods-entomophagous insects of harmful lepidoptera and pollinators of apple trees were conducted on 23 June 4 July 2021 in the south-east of Kazakhstan (Almaty region, Karasay district, vicinity of the village of Kairat, farm "Olzhas", N 43°09'32.6", E 76°33'33.8"; 898.75 m above sea level). The station is hilly foothills with small ravines. The soil is foothill dark brown. The variety of apple trees on which the tests were carried out is "Aport", the age of the trees is 15-20 years. The block diagram of the research design is presented in Fig. 1.

As indicator species, we selected widespread entomophagous insects and pollinators with well-known biology and ecological features that were often found at monitoring sites. The indicator species of arthropods are shown in Figs. 2 to 15 made by the authors in 2021. 4 species of spiders from 4 families with different ecologies were taken from arachnids: *Araniella cucurbitina* Clerck, 1757, Araneidae (Fig. 2, ambush predator weaving open classical trap nets), *Phylloneta impressa* Koch, 1881 (Fig. 3, ambush predator weaving hidden dome-shaped trap nets), Theridiidae, *Spiracme striatipes* Koch, 1870, Thomisidae (Fig. 4, ambush predator that does not weave fishing nets), and *Pardosa agrestis* Westring, 1861, Lycosidae (Fig. 5, active running predator). Of insects-2 species of hemiptera (Hemiptera) -*Nabis ferus* Linnaeus, 1758, Nabidae (Fig. 6, predator of the grass tier) and *Xylocoris cursitans* Fallen, 1807, Anthocoridae (Fig. 7, predator of the tree-shrub tier); 2 species of coleoptera (Coleoptera)-*Pterostichus nigrita* Paykull, 1790, Carabidae (Fig. 8, a secretive, active predator) and *Coccinella septempunctata* Linnaeus, 1758 and Linnaeus, 1758, Coccinellidae (Fig. 9, open-living active predator); 4 species of Hymenoptera-*Itoplectis tunetana* Schmiedeknecht, 1914 (Fig. 10, caterpillar parasite), Ichneumonidae, single bee *Halictus quadricinctus* Fabricius, 1776 (Fig. 11, pollinator, nests in the ground), Halictidae and the solitary bee *Megachile rotundata*

Fabricius, 1787 (Fig. 12, pollinator, nests in empty plant stems and wood), Megachilidae and *Lasius niger* Linnaeus, 1758 ant (Fig. 13, predator with a mixed diet of aphids and nectar), Formicidae; 2 species of diptera-*Scathophaga stercoraria* Linnaeus, 1758 (Fig. 14, active predator), Scathophagidae and babbler *Sphaerophoria scripta* Linnaeus, 1875 (Fig. 15, aphid entomophagous insects and pollinator), Syrphidae.

The collection of the material was carried out by mowing with a standard entomological net with a diameter of 30 cm, with a handle length of 1 m. The mowing of 25 strokes of the net in 5 repetitions was taken as a unit of accounting. The mowing evenly covered both the lower and upper tiers of the vegetation cover. The materials of each repetition were folded separately into plastic stains with cotton wool soaked with ethyl acetate or jars with 70% ethyl alcohol. Each collection was provided with an appropriate label to identify the material (with information about the conditions of material collection). After brewing the objects, the material was placed on paper mattresses with a label for subsequent in-house processing and storage in laboratory conditions.

Also, soil traps of the original modification were used to carry out records of terrestrial fauna-cut plastic bottles with a volume of 0.25-1 liters, dug into the soil at an equal distance from each other (Temreshev *et al*., 2016). The materials collected in this way, after drying, were laid out on entomological mattresses or fixed in 70% ethyl alcohol. The records were carried out on the day before treatment (0) and on the 3rd, 5th, 7th, 9th, and 14th days after treatment.

In addition, visual accounting, photographing, and manual collection of arthropods were used on vegetation, trunks, and branches of apple trees, in hunting belts, under bark, and in various shelters (stones, pieces of trees, mown hay, etc.).

The treatment of experimental plots with biological preparations was carried out on 29.06.2021 with a mounted garden sprayer "Agrola Art 1000 I"-P 161/2 ("Agrola", Poland). The size of plots for each preparation was 0.25 hectares (50 m x 50 m), with 10 apple trees on each. The effect of biological preparations Phytoverm ® K.E. (emulsion concentrate, aversectin C, a natural mixture of four avermectins B1a, A1a, A2a, B2a, produced by *Streptomyces avermectilis* microorganisms, Pharmbiomed, Russia), Lepidocide ® S.K. (suspension concentrate of the spore-crystal complex *Bacillus thuringiensis var. kurstaki*, biological activity BA 3000 EA/mg, suspension concentrate, according to Sibbiopharm, Russia), Green Gold, 0.3% by weight (azadirachtin, oil emulsion, 0.3%, Shynzhan Ruihyn Biotechnology Company, China) and Entolek Planteco K ® (strain of the entomopathogenic fungus *Akanthomyces lecanii* (=*Lecanicillium lecanii*), a titer of at least 2 billion spores/mL, "Biopreparat", Russia) for different types of entomophagous insects and pollinators of apple trees.

The rate of consumption of biological preparations was 1.3 L/ha for Phytoverm ® CE, 2 L/ha for Lepidocide ® SC, 0.45-0.75 L/ha for Greene Gold, 0.3% wt. e. and 0.2 L/ha for Entolek Planteco K ®.

The water used for the treatments had a pH = 7-8, i.e., a slightly alkaline reaction. The chloride content in the water was 78.16-93.56 mg/L, which did not exceed the current GOST-350 mg/L. Thus, the water had no negative properties that interfere with the normal activity of microorganisms and active substances, which were the active basis of biological products. The territory of the garden is used for eco-tourism, so it has not previously been treated with chemical insecticides.

The Microsoft Excel 2013 program was used to plot the number of indicator arthropod species. Statistical processing was carried out using the program R.

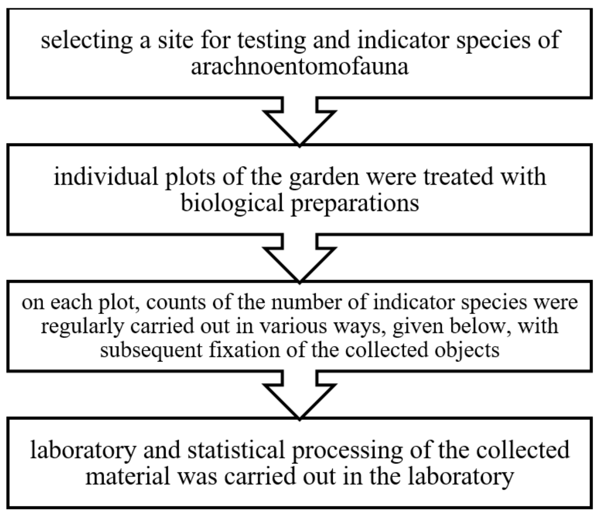

Fig. 1: Research design

Fig. 2: *Araniella cucurbitina*

Fig. 3: *Phylloneta impressa*

Fig. 4. *Spiracme striatipes*

Fig. 5: *Pardosa agrestis*

Fig. 6: *Nabis ferus*

Fig. 7: *Xylocoris cursitans*

Fig. 8: *Pterostichus nigrita*

Fig. 9: *Coccinella septempunctata*

Fig. 10: *Itoplectis tunetana*

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Fig. 11: *Halictus quadricinctus*

Fig. 12: *Megachile rotundata*

Fig. 13: *Lasius niger*

Fig. 14: *Scathophaga stercoraria*

Fig. 15: *Sphaerophoria scripta*

Results

For the entire time of the accounting, 8720 arthropod specimens belonging to 14 families and 5 orders from 2 classes-arachnids (Aranei) and insects (Insecta) were taken into account. The following results were obtained on the dynamics of the number of indicator species of spiders and insects in the areas treated with biological preparations. On the 3^{rd}-5^{th} day after treatment, the number of *Araniella cucurbitina* and *Phylloneta impressa* spiders decreased quite sharply on the sites treated with Phytoverm ® CE and Greene Gold bipreparations, 0.3% by weight (Fig. 16A-B). Then there was a gradual increase, but none of the species reached the initial level until the 14th accounting days. The most noticeable was the decrease in the number of *A. cucurbitina*. In areas treated with Entolek Planteco K ® and Lepidocide ®. The decrease in the number of SC was quite insignificant, and its complete recovery

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occurred within 1 week after treatment, especially in the variant with the drug Lepidocide ® SC (Fig. 16C-D).

As for other indicator spider species *Spiracme striatipes* and *Pardosa agrestis*, the situation was similar. A sharp and prolonged decline in the number of both species was also recorded in the plots treated with Phytoverm ® CE and Greene Gold bipreparations (Fig. 17A-B). Whereas in the plots with Entolec Planteco K ® and Lepidocide ® However, the fluctuations in the number were very small (Fig. 17C-D).

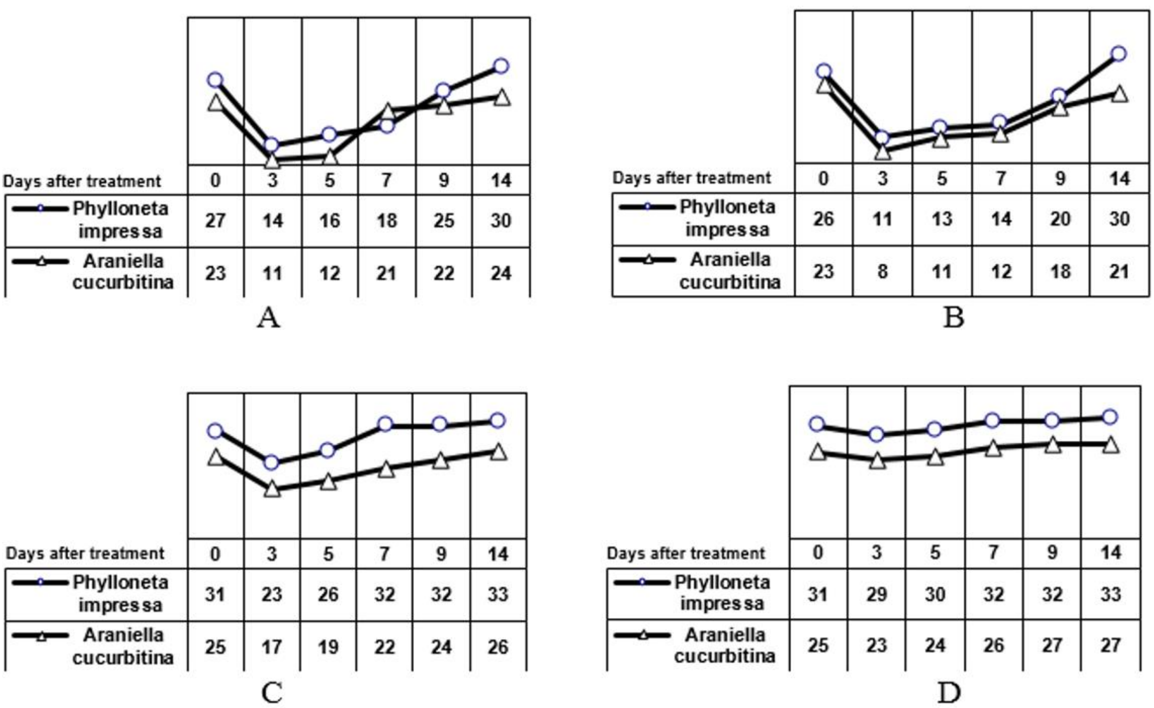
Predatory hemiptera *Nabis ferus* and *Xylocoris cursitans*, as well as spiders, reacted approximately equally to treatments with biological preparations (Fig. 18A-D). The population recovery of *X. cursitans* was faster than *N. ferus*.

Coleoptera insects-ground beetle *Pterostichus nigrita* and ladybug *Coccinella septempunctata*-generally corresponded to the above trends in the abundance of other entomophagous insects. The exception was that on almost all sites treated with insecticides, the number of *P. nigrita* on the 14th day even exceeded the initial one (Fig. 19A-D). The ladybug *C. septempunctata*, showed sharper fluctuations in numbers, especially in the variant with the drug Greene Gold, 0.3% by weight.

The indicator species of entomophagous hymenoptera-the rider *Itoplectis tunetana* and the black garden ant *Lasius niger* on the 7-9th day after a sharp drop completely restored their numbers. The more mobile and numerous garden ant, living in large colonies, and powerful to hide from the effects of drugs in its underground nests, recovered faster than the rider, in all variants (Fig. 20A-D). As in the previous species, the decrease in the number of both types of entomophagous insects on biopesticides treated with Phytoverm ® CE and Greene Gold, 0.3% wt. e. The number of sites was significantly higher than in the areas treated with Entolec Planteco K ® and Lepidocide ® SC.

Indicator species of hymenoptera-pollinators *Halictus quadricinctus* and *Megachile rotundata* also reacted more strongly to treatment with Phytoverm ® CE and Greene Gold, 0.3% by weight, than Entolek Planteco K ® and Lepidocide ® SC (Fig. 21A-D).

Representatives of diptera entomophagous insects-*Scathophaga stercoraria* and *Sphaerophoria scripta* reacted rather poorly to treatments, except variants with the preparations Greene Gold, 0.3% wt. e. and Phytoverm ® CE (Fig. 22, 11-12). Their number decreased slightly throughout the entire observation period. But, like the previous groups, diptera reacted more strongly to treatment with the above drugs than Entolec Planteco K ® and Lepidocide ® SK. Here, the factor of the effect of drugs on the larvae of these flies, especially on *S. scripta* aphids living openly in colonies, could play a role.



A

Days after treatment	0	3	5	7	9	14
Phylloneta impressa	27	14	16	18	25	30
Araniella cucurbitina	23	11	12	21	22	24

B

Days after treatment	0	3	5	7	9	14
Phylloneta impressa	26	11	13	14	20	30
Araniella cucurbitina	23	8	11	12	18	21

C

Days after treatment	0	3	5	7	9	14
Phylloneta impressa	31	23	26	32	32	33
Araniella cucurbitina	25	17	19	22	24	26

D

Days after treatment	0	3	5	7	9	14
Phylloneta impressa	31	29	30	32	32	33
Araniella cucurbitina	25	23	24	26	27	27

Fig. 16: Dynamics of the number of indicator spider species *Araniella cucurbitina* and *Phylloneta impressa* in areas treated with bipreparations: A-Phytoverm ® CE; B-Greene Gold, 0.3% wt. e.; C-Entolek Planteco K ®; D-Lepidocide ® SK

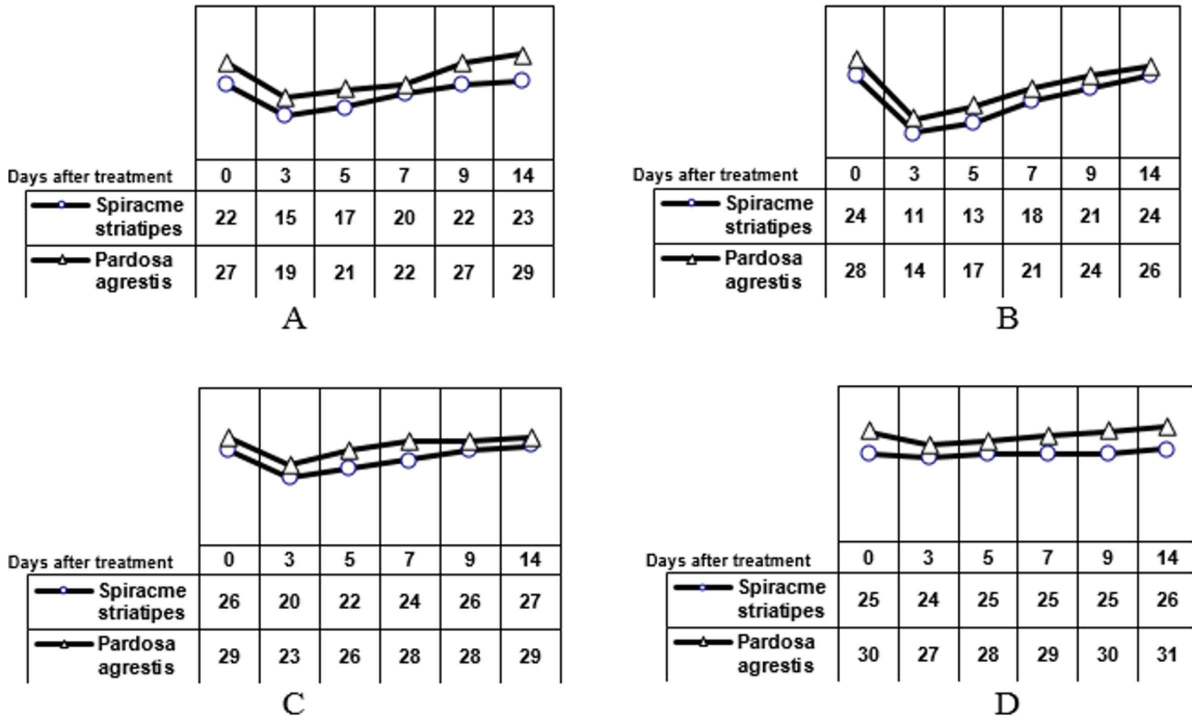


Fig. 17: Dynamics of the number of indicator spider species *Spiracme striatipes* and *Pardosa agrestis* in areas treated with bi-preparations: A-Phytoverm ® CE; B-Greene Gold, 0.3% wt. e.; C-Entolek Planteco K ®; D-Lepidocide ® SK

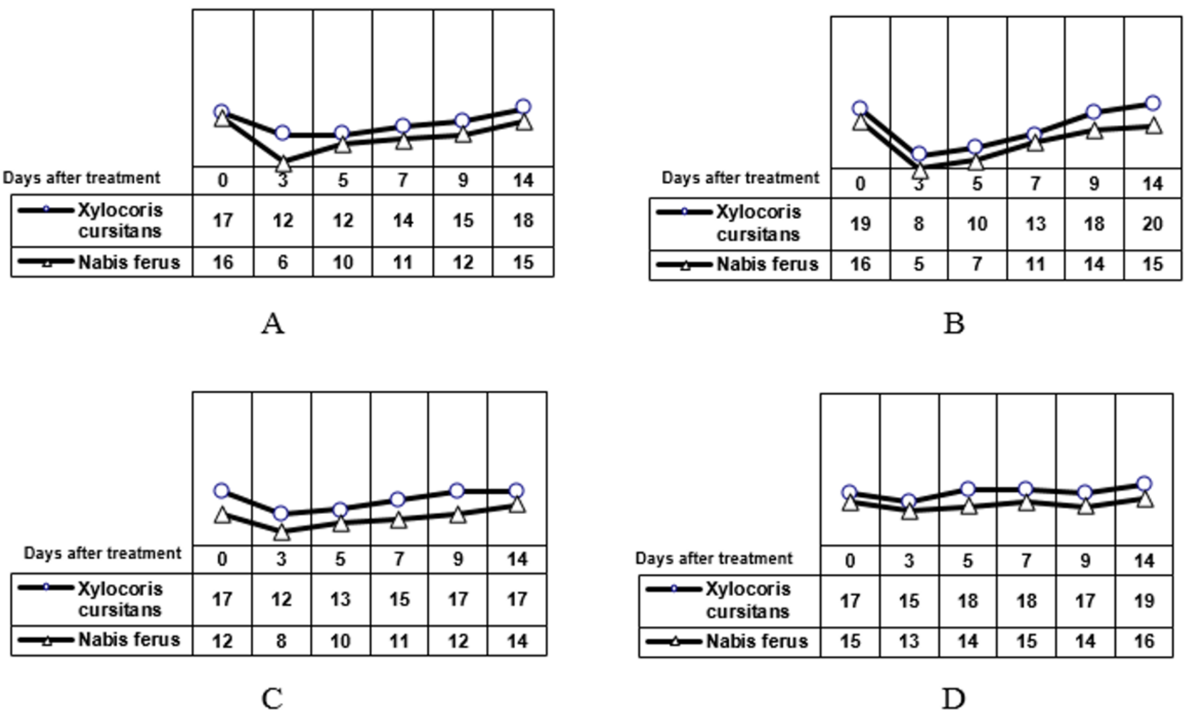


Fig. 18: Dynamics of the number of indicator species of hemiptera *Nabis ferus* and *Xylocoris cursitans* in areas treated with bi-preparations: A-Phytoverm ® CE; B-Greene Gold, 0.3% wt. e.; C-Entolek Planteco K ®; D-Lepidocide ® SK

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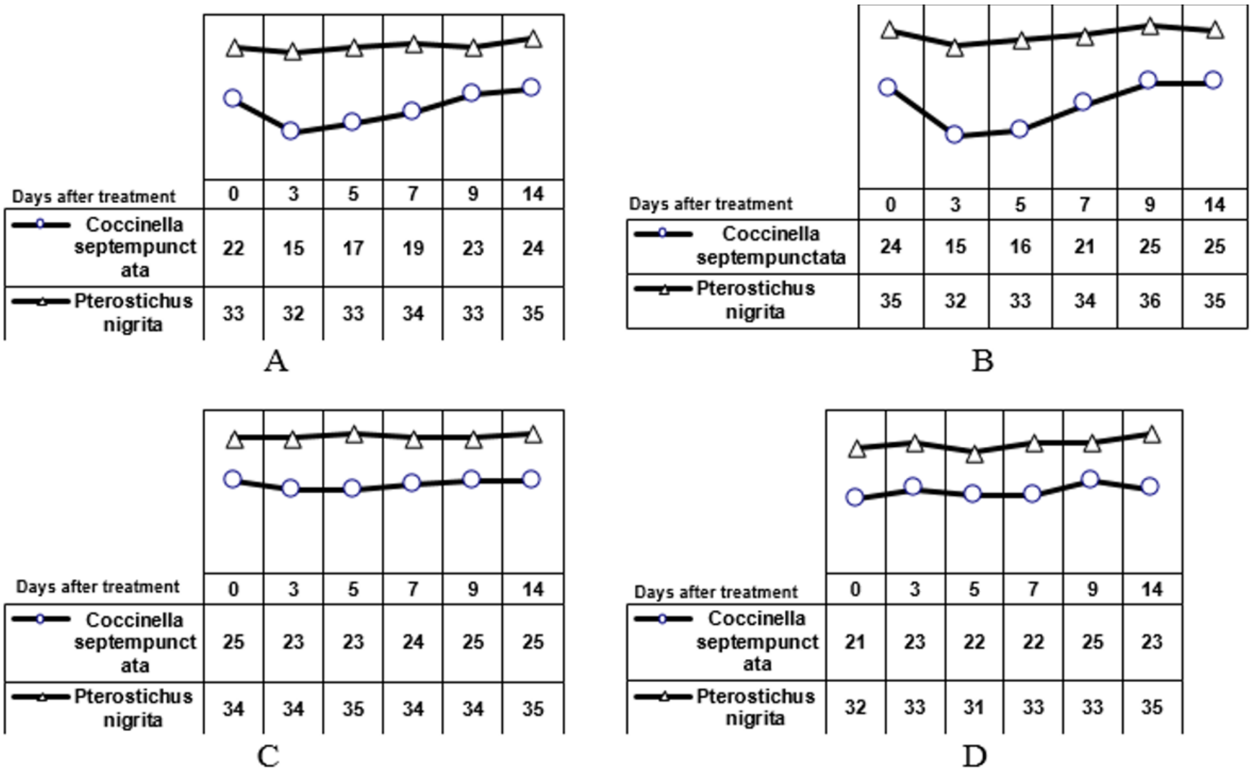

Fig. 19: Dynamics of the number of indicator species of coleoptera *Pterostichus nigrita* and *Coccinella septempunctata* in areas treated with bi-preparations: A-Phytoverm ® CE; B-Greene Gold, 0.3% wt. e.; C-Entolek Planteco K ®; D-Lepidocide ® SK

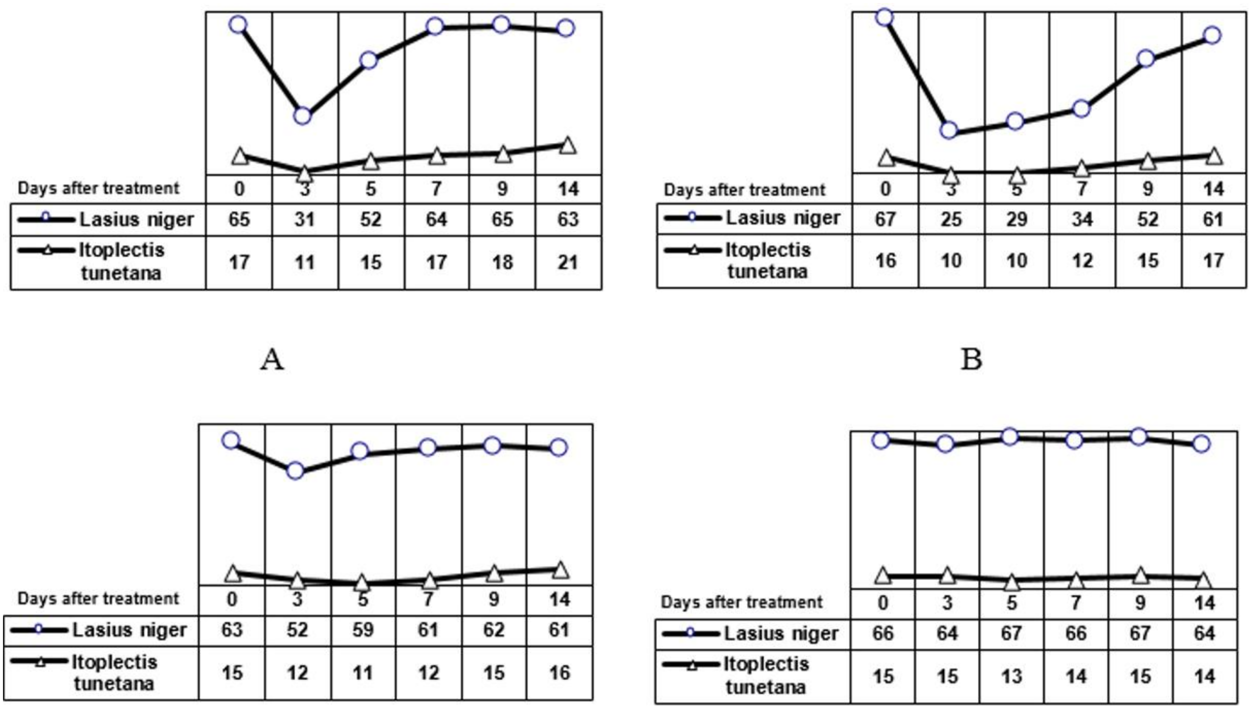

Fig. 20: Dynamics of the number of indicator species of entomophagous hymenoptera *Itoplectis tunetana* and *Lasius niger* in areas treated with bi-preparations: A-Phytoverm ® CE; B-Greene Gold, 0.3% wt. e.; C-Entolek Planteco K ®; D-Lepidocide ® SK

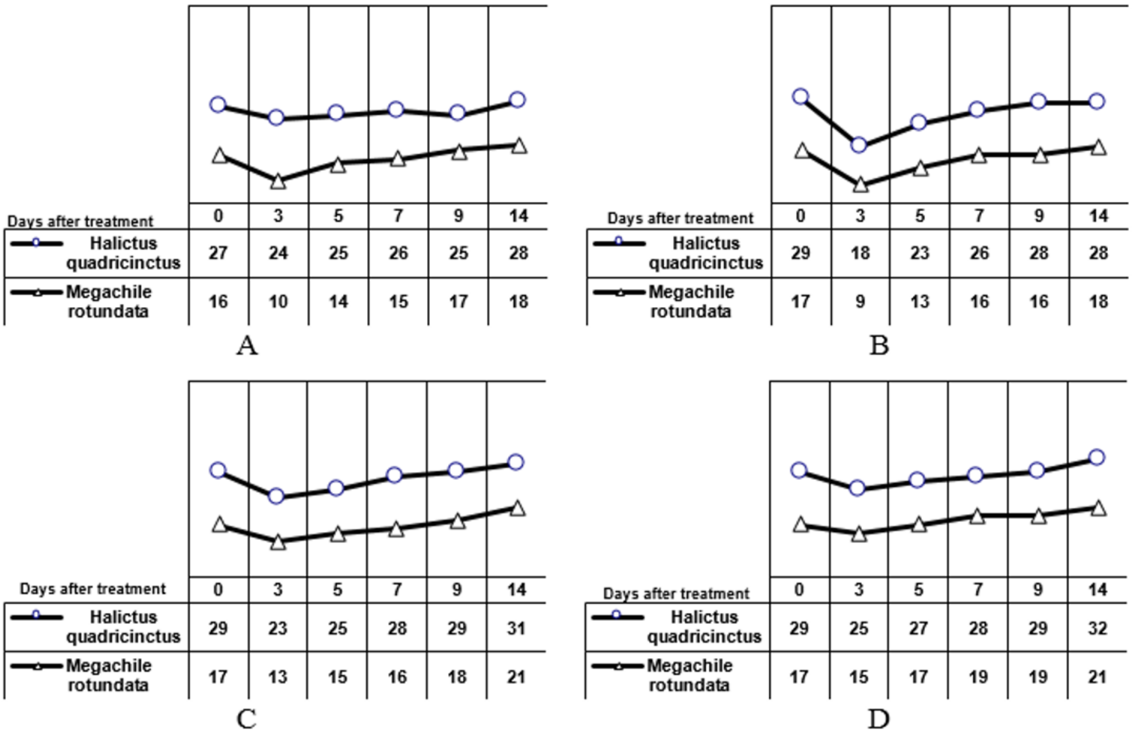

Fig. 21: Dynamics of the number of indicator species of hymenoptera-pollinators *Halictus quadricinctus* and *Megachile rotundata* in areas treated with bi-preparations: A-Phytoverm ® CE; B-Greene Gold, 0.3% wt. e.; C-Entolek Planteco K ®; D-Lepidocide ® SK

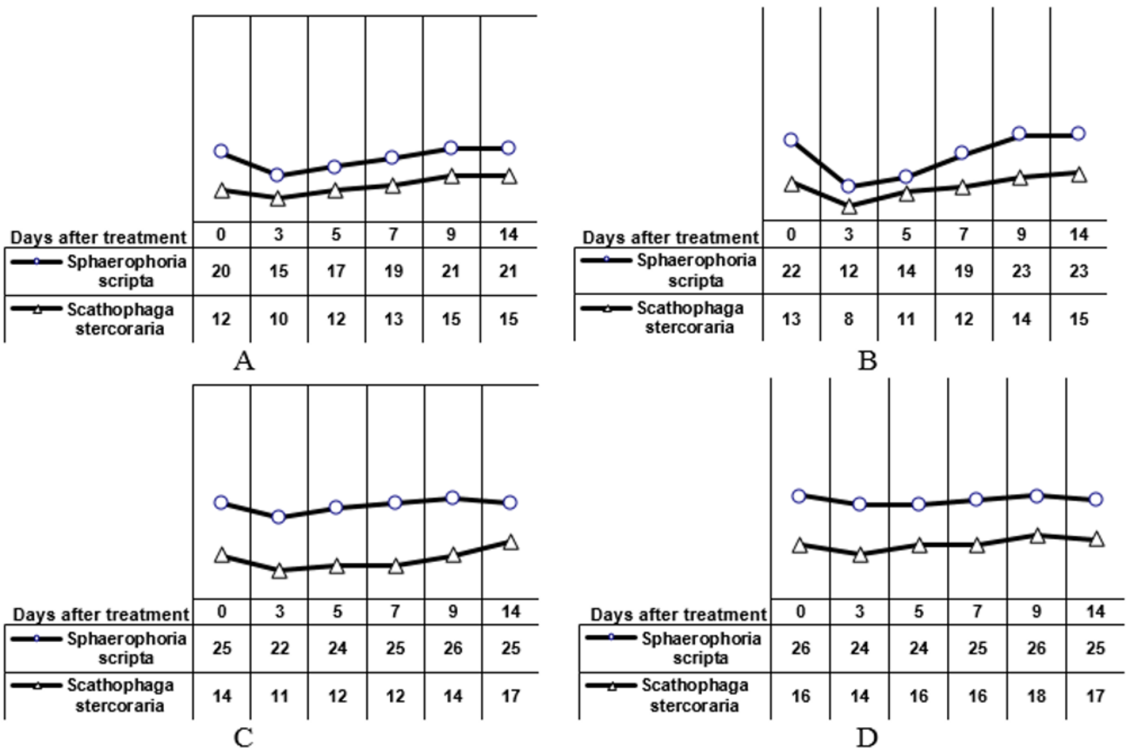

Fig. 22: Dynamics of the number of indicator species of diptera *Scathophaga stercoraria* and *Sphaerophoria scripta* in areas treated with bi-preparations: A-Phytoverm ® CE; B-Greene Gold, 0.3% wt. e.; C-Entolek Planteco K ®; D-Lepidocide ® SC

Discussion

As can be seen from the data we obtained, all the tested bioinsecticides and biorational preparations had different effects on indicator species of entomophagous insects and pollinators.

Green Gold (Azadirachtin)

The most noticeable was the decrease in the number of *A. cucurbitina*. This is due to its lifestyle-this spider is an ambush predator, weaving open classic fishing nets. That is, when carrying out treatments, there is a greater chance that drops of the drug will fall on spiders. In addition, with an open lifestyle, the probability of surviving is less, since there is more opportunity to get under the mechanical influence during processing. It was noted that the number of the wolf spider *P. agrestis* recovered faster-these arachnids are quite mobile and have more opportunities to migrate from the treated areas and then populate the deserted territories after the end of the drug. Crab spiders *S. striatipes* are slower due to their lifestyle, so their numbers recovered more slowly. The active substance of this drug is azadirachtin extracted from the fruits and seeds of the neem tree (*Azadirachta indica*). The main property of azadirachtin is its effect as an antifidant - an organic substance produced by the plant itself, for the destruction of insects that eat it. In our experiments, the negative effect of the drug was traced, especially for species weaving permanent fishing nets (*A. cucurbitina* and *P. impressa*). In experiments with the spider *Oxyopes lineatus* Koch, 1847, azadirachtin had a small lethal effect on it and reduced the level of predation (Košulič *et al*., 2018; Allahvaisi *et al*., 2021). For the spider *Philodromus cespitum* Walckenaer, 1802, there was a decrease in the predation risk response and an effect on mating behavior in contact with azadirachtin residues (Nawrocka, 2008; Sentenská *et al*., 2021). There is information about a decrease in the activity as a predator of the entomophagous bug *Cyrtorhinus lividipennis* Reuter, 1885 under the action of this substance (Wei *et al*., 2019). Two species of predatory beetles (Coleoptera) reacted differently to the treatment of Green Gold, 0.3% by weight. There is information that another species of ground beetles-*Anchomenus dorsalis* Pontoppidan, 1763 also did not suffer when treated with azadirachtin (Marohasy and Forster, 1991). In addition, after treatment with the drug, she lost her food base-aphids and other colonial hemiptera-phytophages, and the beetles were forced to leave the sites in search of food. According to available information, in laboratory experiments, *C. septempunctata* imagos did not show increased mortality or decreased fertility compared to the untreated control, but larval metamorphosis was interrupted, pupal death and the appearance of imagos with deformed wings were observed (Oswald, 1989; Kaethner, 1990; Mitchell *et al*., 2004). According to other information, azadirachtin treatment in the field caused complete infertility or decreased oviposition in the imago of this beetle species, and also contributed to the complete death of larvae within 10 days (Banken and Stark, 1998). Among useful hymenoptera (Hymenoptera) with different lifestyles, a different reaction was also observed. Its negative effect was also observed on riders *Trichogramma spp.*, and many other species of parasitoids (Solis *et al*., 2004; Raguraman and Kannan, 2014; Dono *et al.*, 2020). The black garden ant *L. niger* is a social insect, very numerous, mobile enough, and able to hide for a while in its underground nests from the effects of drugs. The death of ants from the action of azadirachtin, for example, leafcutters *Atta spp.*, *Oecophylla smaragdina* Fabricius, 1775 and *Acromyrmex subterraneus* Trout, 1893, is reported in many works (Amaral *et al*., 2019; Presa-Parra *et al*., 2021; Selvam and Nalini, 2021). According to the List of pesticides in the Republic of Kazakhstan (State Inspection Committee in the Agro-industrial complex, 2020), Greene Gold, 0.3% belongs to class P-4. That is, after its application, it is necessary to limit the summer of bees to 6-12 h. But since the flight of solitary wild bees, unlike the domestic honey bee, cannot be artificially limited, they are more susceptible to the influence of the drug. Moreover, it has a stronger effect on the alfalfa bee-leaf cutters *M. rotundata.* Due to its biology, this species lives in the hollow stems of plants, and nests right on the territory of the garden, so it stays in the processing zone for a longer time. The *H. quadricinctus* bee lives in earthen burrows in open areas of soil outside the experimental garden, and its stay in the treated area is thus less. According to available information, when treated with 1% neem seed extract, the number of coriander pollinators decreased 1 day after application (Singh *et al*., 2010). Azadirachtin is known to have a negative effect on bumblebees *Bombus terrestris* Linnaeus, 1758 even at concentrations 50 times lower than the recommended levels used by farmers. In the laboratory, males of the colony did not hatch from larvae fed with recommended levels of pesticide, and even at concentrations 50 times lower, the hatched males were deformed and significantly smaller compared to the untreated colony (Barbosa *et al*., 2015; van Dyke *et al*., 2018). There are similar data on the honey bee *Apis mellifera* Linnaeus, 1758, in which the drug, in addition to the above symptoms, caused a decrease in appetite, movement speed, premature and abnormal pigmentation on the oral apparatus, and other appendages of the pre-pupae (Xavier *et al*., 2015). In females of the ruthless bee *Partamona helleri* (Friese, 1900), azadirachtin led to a decrease in fertility and survival, a decrease in size, and caused body development disorders (Bernardes *et al*., 2018). Thus, our results and the available international information demonstrate the potential acute toxicity of azadirachtin, and indicates the importance of assessing the risks of side effects of biopesticides, often advertised as harmless to the environment, on non-target organisms such as pollinators. Entomophagous insects from the order Diptera (*S. stercoraria* and *S. scripta*) also reacted negatively, although less strongly than other indicator species, to treatment with this drug. There is information that the larvae of the fly are syrphids *Episyrphus balteatus* De Geer, 1776 die en masse when treated with a drug based on azadirachtin (Schauer, 1985), and the number of imago syrphides *Eupeodes fumipennis* Thomson, 1869 decreases sharply after treatments (Fernandez *et al*., 1992; Lowery and Isman, 1996). There was a strong decrease in the yield of imago syrphids from larvae collected on peach trees treated with neem extract (Eisenlohr *et al*., 1992). There is also a report of a decrease in the number of predatory diptera (Cecidomyiidae) in the field after the use of 1% neem seed extract and neem oil (Lowery and Isman, 1996).

Phytoverm (Avermectins)

Less strong, but also noticeable, was the effect of the biopesticide Phytoverm ® CE, especially in the first days after the treatment. Its active substances, avermectins, are known for their toxicity to arachnids-spider mites, as well as predatory mites and ixod mites (Temreshev *et al*., 2018a; Temreshev *et al*., 2019). The mortality of the spider *Pardosa pseudoannulata* Bösenberg and Strand, 1906 from abamectin was 17.78%, and that of the spider *Oxyopes javanus* Thorell, 1887 was 14.01% (Islam and Das, 2017). Previously, in our laboratory experiments, the avermectin-based drug Actarophyte had a strong effect on the cruciferous bedbug *Eurydema ornata* Linnaeus, 1758 (Temreshev *et al*., 2018b). Tests conducted in the field on potatoes showed that the drug Phytoverm ® CE at a dose of 0.4 L/ha has a toxic effect on the larval stages of predatory bedbugs, so on the 7th day the survival rate of larvae of *P. maculiventris* I-II age decreased sharply, *P. bioculatus* - was 0%. The imagos of predatory bedbugs were less sensitive to the action of the drug: The survival rate of *P. maculiventris* reached 81.8%, *P. bioculatus*-90.9% (Agas'eva *et al*., 2019). As in the case of azadirachtin, two species of predatory beetles (Coleoptera) reacted differently to treatment with ivermectin. According to available information, the mortality rate from this substance for the Asian ladybug *Harmonia axyridis* (Pallas, 1773) was similar to our data -33.3%, according to another it was 14.66% (Islam and Das, 2017). According to Russian scientists, the drug Fitoverm ® CE at a dose of 1.3 L/ha did not affect the viability of imago of ladybirds *C. sangvinea* and *H. axyridis* (survival rate was 85.0 and 87.7%, respectively). The older larvae of both species were resistant to the drug, and the younger larvae of *C. sanguinea* completely died on the 7th day. After the eggs were processed, the larvae hatched, and then their complete (100%) death occurred with 100% survival in the control (Agas'eva *et al*., 2019). According to available information, avermectin (MK-0234) showed minimal adverse effects for the parasitoids *Pteromalus puparum* Linnaeus, 1758 and *Cotesia orobenae* Forbes, 1883 (Kok *et al*., 1996). According to another, avermectins are recommended in the USA as a means of combating the fire ant *Solenopsis invicta* Buren, 1972, which leads to infertility of its females and the gradual extinction of the colony (Drees and Vinson, 1993). Thus, their prolonged effect on entomophagous hymenoptera should be studied in more detail, and carefully evaluated when planning joint use. There is evidence that the remnants of avermectin were slightly toxic (<20% mortality) for the honey bee *A. mellifera*, as well as several species of predators and parasitoids within a day after application and often within a few hours after application. Low toxicity was associated with a short half-life. However, in more recent literature sources it is noted that abamectin causes digestive disorders in honey bees, affecting the health and viability of the colony, and ivermectin causes long-term memory disorders (May *et al*., 2015; Aljedani, 2017; Domatskaya *et al*., 2018). Acute oral toxicity of abamectin for *B. terrestris* bumblebees was revealed (Marletto *et al*., 2003). Currently, new methods for assessing the effects of various pesticides are being actively discussed and developed, including avermectins, on pollinators, due to the shortcomings of the existing risk assessment system (EFSA, 2013; Mahefarisoa *et al*., 2021). In several sources, they are already classified as high-risk drugs for bees and other pollinators (Mahefarisoa *et al*., 2021). According to literature data, avermectins cause increased adult mortality, developmental delay, and abnormalities, larval death, decreased mating attempts, and fertility in diptera from different families: *Musca domestica* Linnaeus, 1758, *Musca nevilli* Kleynhans, 1987, *Musca vetustissima* (Walker, 2017), *Haematobia irritans* (Linnaeus, 1758) (Muscidae), *Neomyia cornicina* Brauer and Bergenstamm, 1893, *Lucilia cuprina* (Wiedemann, 1830) (Calliphoridae) and *S. stercoraria* (Scatophagidae).

Entolek Planteco K ® (Akanthomyces lecanii)

The active substance of the Entolek Planteco K ® is the fungus *A. lecanii*, the toxicity of which is known for some arachnids-various Phytophagous mites and predatory mite *Phytoseiulus persimilis* Athias-Henriot, 1957 (Zenkova *et al*., 2020). According to available data, the mortality rate of the imago bug *Orius laevigatus* Fieber, 1860 when sprayed with Verticillin M (a biological preparation based on *A. lecanii*) was 22-61%, depending on the concentration of the drug. There was no toxic effect on bug larvae, and their combined use with Verticillin M is recommended (Mitina *et al*., 2018). The number of ground beetle *P. nigrita* on the site treated with

Entolek Planteco K ® to *P. nigrita* on the site treated with has not changed practically during the entire time of the records. A strong effect of Entolec Planteco K ® on the abscess beetle *Lytta togata* Fisher von Waldheim, 1844, is known (Temreshev *et al*., 2020). For the ladybug *Cheilomenes sexmaculata* Fabricius, 1781, the difference between the numbers in the experimental version with *A. lecanii* and the control was only 0.14%, and for the staphylin beetle *Paederus sp*.-4.54% (Winarsih and Asri, 2020). According to other data, *A. lecanii* can infect and cause the death of up to 50% of adult individuals of *Ch. sexmaculata* (Shinya *et al*., 2008; Hadi *et al*., 2020). There is evidence of the possibility of joint use of *A. lecanii* and the rider *Encarsia formosa* Gahan, 1924 (Stansly and Liu, 1997; Mitina *et al*., 2018; Gogi *et al*., 2021). According to available data, when sprayed with different types of entomopathogenic mushrooms of the bumblebee *B. terrestris* and the honey bee *A. mellifera*, the fungus *A. lecanii*, which is the active ingredient of this biological product, had the lowest negative effect of all of them (Akkoç *et al*., 2019; Erler *et al*., 2022). According to literature data, the preparation Verticillin M based on the fungus *A. lecanii* was slightly toxic for the predatory diptera *Aphidoletes aphidimyza* (Rondani, 1848) used in a biometode against aphids- 37.5% on day 3 and 57.5% on day 6 (Mitina *et al*., 2018).

Lepidocide ® SC (Bacillus thuringiensis)

The toxicity of *Bacillus thuringiensis*–based preparations Lepidocide ® SC, 8, 6.45, 4 and 10% is known for some arachnids - various phytophagous mites (*Panonychus citri* (McGregor, 1916), *Tetranychus urticae* Koch, 1836, etc.) and predatory ticks (*Phytoseiulus persimilis* Athias-Henriot, 1957, *Galendromus occidentalis* (Nesbitt, 1951), etc.) (Zenkova *et al*., 2020). In our studies on the drug AkKobelek ™ based on *B. thuringiensis*, its negative effect on spiders from different families (Araneidae, Salticidae, Lycosidae, Pisauridae, Therediidae and Thomisidae) was not noted (Temreshev *et al*., 2018a; 2018b). According to the results of research by Russian scientists, it was found that this drug is not toxic to predatory Miridae bugs (Dolzhenko *et al*., 2016). In our studies on the drug AkKobelek ™ based on the strain of *B. thuringiensis*, its toxicity to predatory bugs from the families Nabidae, Reduviidae, and Anthocoridae was not observed (Temreshev *et al*., 2018a; 2018b). According to the results of research by Russian scientists, it was also found that this drug is nontoxic for coccinellides (Awasthi *et al*., 2013; Dolzhenko *et al*., 2016). Previously, in our studies on the drug AkKobelek ™ based on the same strain of *B. thuringiensis*, its toxicity was not observed for coleoptera from different families-Carabidae, Staphilinidae, Histeridae, Cantharidae, and Coccinellidae (Temreshev *et al*., 2018a; 2018b). In our studies on the drug AkKobelek ™ based on the same strain of *B. thuringiensis* as in Lepidocide ® SC, its toxicity to hymenoptera-riders and ants, as well as burrowing and folded-winged wasps was not observed (Temreshev *et al*., 2018a; 2018b). There is information that after treatment with this drug, the survival rate of the *Habrobracon hebetor* parasitoid population (Say, 1836) was 79.8%, and the yield of *Aphidius colemani* Viereck, 1912 rider from pupae was 38.2% (Agas'eva *et al*., 2019). According to the effect of preparations based on *Bacillus thuringiensis var. kurstaki* on pollinators there are data of a different nature. Some sources claim their safety for the bumblebee *B. terrestris* and the bee *A. mellifera* (WHO, 1999; Erler *et al*., 2022). Previously, in our studies on the drug AkKobelek ™ based on this strain, its toxicity to pollinators was not observed (Temreshev *et al*., 2018a; 2018b). Other authors write about an increase in mortality, a decrease in nutritional activity, and physiological changes in the already mentioned species and the wax bee *Apis cerana* Fabricius, 1793 (WHO, 1999; Erler *et al*., 2022). Currently, new methods for assessing the effects of various pesticides are being actively discussed and developed, including those based on *B. thuringiensis*, on pollinators, due to the shortcomings of the existing risk assessment system (Steinigeweg *et al*., 2021). In our studies on the drug AkKobelek ™ based on the strain of *B. thuringiensis*, its toxicity to diptera entomophagous insects-Syrphidae and Asilidae was not observed (Temreshev *et al*., 2018a; 2018b). In general, it is known that a large number of families of diptera insects (Culicidae, Glossinidae, Muscidae, Calliphoridae, Tephritidae, Simuliidae, Chironomidae, Tipulidae, Agromyzidae, Drosophilidae) are affected by strains of B. thuringiensis, but these are strains of var. *israelensis*, *jegathesan*, *darmstadiensis*, *kyushensis*, *medellin*, *fukuokaensis*, *higo*, and not the var we tested *kurstaki* (Valtierra-de-Luis *et al*., 2020).

As mentioned above, in addition to direct elimination due to exposure to biopesticides, the decline in the number of all these arthropods depends on the fact that most of them are predators. In fact, after processing, they lost their food source-phytophagous insects, which also died as a result of exposure to biological products, so the surviving individuals migrated in search of food to untreated areas. In addition, some of the drugs have a repellent smell.

At the control site, the number of indicator species-both arachnids and insects-varied within acceptable limits for garden bioceonosis.

Conclusion

Based on the results obtained, our goal for the study was achieved. The following conclusions were made.

From the results of our research and a review of the available international scientific data, it is clear that the bioinsecticide Greene Gold, 0.3% by weight (azadirachtin) has a rather significant negative effect on non–target organisms-entomophagous insects and pollinators. Based on this, its use in protecting the apple orchard from harmful lepidoptera should be carefully evaluated. When using this drug in the organic production of agricultural products and integrated plant protection, a pause of at least 7 days should be maintained between the processing and the release of entomophagous insects so that the remnants of the drug do not have a negative effect on the beneficial arachno entomofauna. For this, special step-by-step schemes should be drawn up. The same is recommended during the mass summer of bees or the use of bumblebees and other artificially bred pollinators.

The use of Phytoverm ® CE biopesticide, although it had a lower negative effect than azadirachtin, judging by the results of our experiments and the available data from foreign colleagues, should be applied the same approach as to the previous bio preparation.

Both Green Gold, 0.3% by weight, and Phytoverm ® CE are desirable to study in more detail in terms of their prolonged action, not only on entomophagous insects and pollinators but also on soil-forming agents, in the conditions of Kazakhstan. Moreover, in world practice, research in this direction is already actively conducted.

Bioinsecticides Entolek Planteco K ® and Lepidocide ® SC have a less significant negative effect on the fauna of entomophagous insects and pollinators and do not reduce the number of spiders as much as the two previous drugs. When choosing biologics for use against harmful lepidoptera in apple orchards in the south-east of Kazakhstan, it is advisable to focus on these bioinsecticides as having a more sparing effect for non-target arachno entomofauna.

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Author’s Contributions

All authors contributed equally to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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