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Review

Biological control of pests in Ukraine: legacy from the past and challenges for the future

Tatyana R. Stefanovska[1,*], Valentina V. Pidlisnyuk[2] and Harry K. Kaya[3]

Address: [1] Department of Integrated Pest Management and Quarantine of Pests, National Agricultural University, Kiev, 03041, Ukraine. [2] Department of Agricultural Extension, National Agricultural University, Kiev, 03041, Ukraine. [3] Department of Nematology, University of California, Davis, CA 95616, USA.

***Correspondence:** Email: tstefanovska@mail.ru

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Abstract

Biological control has a long and rich history in Ukraine which is closely linked with other countries of the Former Soviet Union, and some relevant studies from these countries are also included in this review. The use of natural enemies against Ukrainian insect pests demonstrates that biological control approaches have enjoyed a degree of success. The release of *Aphelinus mali* in a classical biological control programme against the woolly apple aphid, *Eriosoma lanigerum*, was successful. In contrast, the release of the hemipterans, *Perillus bioculatus* and *Podisus maculiventris*, against the Colorado potato beetle, *Leptinotarsa decemlineata*, was not successful, and studies in the use of these hemipterans as biological control agents continue. Conservation biological control is practised in apple and cereal cropping systems resulting in a number of predators and parasitoids being preserved. Augmentation of natural enemies, especially predatory mites against the spider mite *Tetranychus urticae* in greenhouse cucumber and tomato production, has provided suppression of this pest. Various strains of *Bacillus thuringiensis* are being used inundatively against lepidopteran, coleopteran and mosquito pests. A granulovirus has been studied for use against the codling moth (*Cydia pomonella*), and the fungus, *Beauveria bassiana*, is being evaluated against several insect pests. Entomopathogenic nematodes have generated some interest for future use in Ukraine as potential biological control agents against soil-inhabiting pests. Although biological control programmes have been practised for many years, the agricultural sector in Ukraine is moving from a command to a market economy. The latter economy is profit-driven and relies more on chemical pesticide usage. The challenge is to integrate biological control programmes into the market economy.

Keywords: Entomopathogens, Entomophagous insects, Natural enemies, Parasitoids, Pathogens, Predators

Introduction

Ukraine has an extensive and varied history in applied biological control in which natural enemies have been used for the regulation of host population densities [1]. Biological control including classical biological control, augmentation, and conservation, has been practised in Ukraine [2, 3], generally quite successfully. There are a number of reasons for the high interest in biological control including the relatively low labour cost, excellent facilities for mass rearing of beneficial organisms, the existence of qualified experts, recognition by local and state officials of the importance of biological control and integrated pest management (IPM) approaches, and the high cost of imported synthetic pesticides. Moreover, increasing awareness among the public about the negative impact of chemical pesticides on the environment and human health creates a favourable atmosphere for the further development of biocontrol programmes.

Ukraine is uniquely positioned to produce biocontrol products including entomophagous insects and entomopathogenic microorganisms at a local level at a much lower cost than for importing them. In this paper, the past and present status of biological control programmes in

Ukraine and, to some extent, relevant publications from other countries of the Former Soviet Union as well as from Europe and North America are reviewed. However, some of the most extensively researched and utilized biological control agents are *Trichogramma* spp. which are only briefly covered in this review. A future review will cover these important biological control agents.

As we look to the future, the use of biological control technology, in large part, will be tied to the shift in the Ukrainian agricultural economy. This aspect is also covered in this review.

Historical overview

The first documentation of successful biological control in the field was in the 19th century in Ukraine when Illya Metchnikoff, Professor of Microbiology at the University of Odessa (southern Ukraine), demonstrated that the green muscardine fungus, *Metarhizium anisopliae* (Metschn.) Sorokin (Hypocreales, Clavicipitaceae), could be used to control the wheat cockchafer, *Anisoplia austriaca* (Herbst) (Col., Scarabaeidae) [4]. Using beer mash as a medium, he produced the fungus, mixed the conidia with soil and placed healthy larvae of the wheat cockchafer into the soil–conidia mixture. Ten days later, he evaluated his experiment and found that eight out of nine larvae had died from a fungal infection. Thus, he is credited with establishing the concept that economically important insects could be intentionally killed by a microorganism. Subsequently, he conducted a similar experiment against another pest, the sugar beet curculio, *Cleonus punctiventris* (Germar) [*Bothynoderes punctiventris*] (Col., Curculionidae) [4]. Shortly thereafter, I. M. Krassilstschik [5] at the University of Odessa utilized Metchnikoff's methods and established a special laboratory to produce conidia of this fungus on a large scale. *Metarhizium anisopliae* was mass produced in Ukraine for use against larvae of the sugar beet curculio.

In 1913, A. Mokerzetskiy in Crimea and V. Pospelov in the Kiev region studied the possibilities of using *Trichogramma* spp. to control the codling moth, *Cydia pomonella* (L.) (Lep., Tortricidae). In the late 1920s and early 1930s, several entomophagous insects were introduced for classical biological control of exotic pests. In 1930, the Institute of Crop Protection in Leningrad was established and recognized as the main research arm for biological control in the entire USSR. N. Meyer led the Biological Methods Unit, which introduced entomophagous insects such as *Rodolia cardinalis* (Mulsant) (Col., Coccinellidae), *Aphelinus mali* (Haldeman) (Hym., Aphelinidae) and *Cryptolaemus montrouzieri* Mulsant (Col., Coccinellidae) to control exotic scale and mealybug pests. Other natural enemies studied included *Telenomus* spp. (Hym., Scelionidae) against *Eurygaster integriceps* Puton (Hem., Scutelleridae).

Insect pathology was also part of the Institute of Crop Protection and was led by V. Pospelov. The unit studied microbiological agents for commercial preparations [6, 7]. In the mid 1940s, Pospelov moved to the Institute of Entomology and Phytopathology in Ukraine. With his move, the research focus of the institute shifted to insect pathology and diseases of beneficial insects [8].

Biological control programmes in Ukraine suffered a major set back with the growing use of synthetic organic chemical pesticides in the 1950s. This situation was not unique to Ukraine as many other countries also began to rely heavily on chemical pest control.

In Ukraine, biological control approaches re-emerged in the late 1950s–early 1960s. This was precipitated by the need to find alternatives to chemical pesticides because of the growing public concern about their use. In 1957, the Institute of Plant Protection (formerly the Institute of Entomology and Phytopathology) created the Department of Microbiological Plant Protection. The main research focus of this group was on the white muscardine fungus, *Beauveria bassiana* (Bals.-Criv.) Vuill. (Hypocreales, Clavicipitaceae). Promising results were obtained with this fungus in combination with insecticides to control the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Col., Chrysomelidae). Telenga [9, 10] developed a method to combine reduced amounts of insecticides with *B. bassiana* that gave good results in controlling the Colorado potato beetle, codling moth and other insects. Research conducted by this group resulted in several published articles on the ecological basis for using predators, parasitoids, and pathogens [11–15].

The Ukrainian government was a primary force in the re-emergence of biocontrol programmes in the 1960s. It issued decrees and orders that encouraged the use of biocontrol agents. A Coordinating Committee on the use of biological methods for plant protection was formed in 1966. This committee consisted of scholars from ten universities and eight research institutions who developed the plans and guidelines for biological control research and its practical application. The biological control approaches became important resulting in the establishment of 13 companies that focused on mass rearing of microbial pathogens, and 268 insectaries for rearing beneficial species, producing parasitoids and predators as well as microbial pathogens of insects and plant diseases in the 1970s. Accordingly, biocontrol agents were used on 1.7 million ha during the 1980s, with the egg parasitoids, *Trichogramma* spp., representing 80% of the agents used. However, the application of synthetic organic chemical pesticides during the 1970s and 1980s was not insignificant with a peak rate of 5.5 kg/ha reported in 1986. Overall, the use of biological control products was considerable during this period, and this lasted until 1991 when the Ukrainian economy started to decline. During a short period beginning in 1991, 40% of the beneficial insectaries were lost. With the reduction in releases of *Trichogramma* parasitoids, outbreaks of lepidopteran

Table 1 Successfully introduced natural enemy(ies) (i.e. classical biological control agents) and their target pest(s)

Date	Natural enemy species (Order, Family)	Exotic pest species (Order, Family)	Region/country
1926	*Aphelinus mali* (Haldeman) (Hym., Aphelinidae)	*Eriosoma lanigerum* (Hausmann) (Hem., Aphididae)	Crimean Ukraine
1931	*Rodolia cardinalis* (Mulsant) (Col., Coccinellidae)	*Icerya purchasi* Maskell (Hem., Margarodidae)	Georgia
1933	*Cryptolaemus montrouzieri* Mulsant (Col., Coccinellidae)	*Pseudococcus gahani* Green [*P. calceolariae* (Maskell)] (Hem., Pseudococcidae), *Pulvinaria aurantii* Cockerell [*Chloropulvinaria aurantii*] (Hem., Coccidae), *Pulvinaria floccifera* Westwood [*Chloropulvinaria floccifera*] (Hem., Coccidae)	Crimean Ukraine, Georgia
1947	*Lindorus lophanthae* (Blaisdell) [*Rhyzobius lophanthae*] (Col., Coccinellidae)	*Chrysomphalus dictyospermi* (Morgan) (Hem., Diaspididae)	Georgia
1947	*Pseudaphycus malinus* Gahan (Hym., Encyrtidae)	*Pseudococcus comstocki* (Kuwana) (Hem., Pseudococcidae)	Trans Caucasus and Middle East, Republics of Former Soviet Union
1960	*Coccophagus gurneyi* Compère (Hym., Aphelinidae)	*Pseudococcus gahani* [*P. calceolariae*] (Hem., Pseudococcidae)	Georgia
1960	*Encarsia formosa* Gahan (Hym., Aphelinidae)	*Trialeurodes vaporariorum* (Westwood) (Hem., Aleyrodidae)	Ukraine
1962	*Allotropa burrelli* Muesebeck *A. convexifrons* Muesebeck (Hym., Platygasteridae)	*Pseudococcus comstocki*	Caucasus, Middle East, Republics of Former Soviet Union
1963	*Phytoseiulus persimilis* Athias-Henriot (Acari, Phytoseiidae)	*Tetranychus urticae* Koch (Acari, Tetranychidae)	Ukraine and other Republics of Former Soviet Union
1967	*Macrocentrus ancylivorus* Rohwer (Hym., Braconidae)	*Grapholita molesta* (Busck) (Lep., Tortricidae)	Russia, Ukraine

pests, especially the European corn borer, *Pyrausta nubilalis* (Hübner) [*Ostrinia nubilalis*] (Lep., Pyralidae), occurred on maize. By 1999, biocontrol products were used on 0.9 million ha and only about 90 small, local beneficial insectaries remained to produce biological control agents. In present day Ukraine, *Trichogramma* spp. are the most commonly used biocontrol agents against a number of lepidopteran pests [16, 17]. They are produced in small, local laboratories on a very limited scale.

Classical biological control with predators and parasitoids

The development of classical biocontrol has been fostered through the introduction of a number of natural enemies to target exotic pests in Ukraine and Russia (Table 1). Classical biocontrol has been employed extensively since the 1920s, and some programmes have been quite successful. Some 26 natural enemies have been successfully introduced and established within the Former Soviet Union countries against 12 exotic arthropod pests. Generally, one in five introductions has resulted in establishment and successful pest suppression (Table 1) [18–20]. However, there have been several projects where the natural enemies did not become established in the release areas because of poor climatic or habitat adaptation or the absence of a host. For example, this occurred with the introduction of predatory pentatomids against the Colorado potato beetle.

Woolly apple aphid

The woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Hem, Aphididae), was first detected in the southern part of the Ukraine's Crimean Peninsula in the early 1920s on apple trees. Subsequently, it was found in the Odessa region in 1926. A classical biological control programme was initiated in 1930 with the importation of the parasitoid *Aphelinus mali* from South America by Meyer [21], which was released in the Crimean region. The parasitoid kept the woolly apple aphid under effective biological control for nearly 40 years as it proved to be a very efficient parasitoid (giving 95–98% parasitism). It has 6–9 generations per year and high fecundity (100 eggs per female). In 1966, however, apple orchards in the Crimean Peninsula experienced significant increases of this aphid pest with reports of several outbreaks. Only 25–30% of the aphid population was parasitized by the parasitoid. The outbreaks were attributed to the intensive use of pesticides which killed beneficial arthropods. By collecting *A. mali* from areas where it still occurred and releasing it into outbreak populations, the woolly apple aphid outbreak populations were reduced to non-damaging levels [22–24].

Colorado potato beetle

The Colorado potato beetle, *Leptinotarsa decemlineata*, invaded Europe in 1877 from the USA where it fed on a number of solanaceous plants, especially cultivated potato. It spread into Ukraine during 1958–1959 and currently is the key pest of potatoes, often causing as much as 66% reduction in crop yield [25]. This pest is a voracious foliage feeder, has a high fecundity, and has 1–2 generations per year [25]. It has a remarkable ability for developing resistance to a great number of chemical insecticides, including organophosphates and pyrethroids [26, 27]. The development of resistance to pyrethroids, for example, can occur in 8–15 generations [28]. Moreover, because the majority of chemical insecticides used on potatoes are not selective, the pest's natural enemies are killed, causing further outbreaks.

In its native home in North America, a number of arthropods are known to attack this pest and some of them show good potential as biocontrol agents [29]. Carabid beetles appear to be particularly abundant. In the USA, the adult carabid beetle, *Lebia grandis* Hentz (Col., Carabidae), feeds on the Colorado potato beetle eggs and larvae [30]. Even in the Former Soviet Union, 14 species of carabids and three species of coccinellids are known to feed on Colorado potato beetle [31]. However, their overall effectiveness at keeping this pest under natural biological control is not known.

Gusev [31] indicated that natural enemies can maintain the population of the Colorado potato beetle below the economic threshold level. For example, two predaceous pentatomid bugs, *Perillus bioculatus* (F.) and *Podisus maculiventris* (Say) have had significant impact on the Colorado potato beetle in Canada. Inundative releases of these pre dators suppressed the beetle density by 62%, reduced defoliation by 86% and increased potato yields by 56% [20].

Perillus bioculatus was introduced in 1964 and *Podisus maculiventris* in 1978 from Canada into Ukraine as classical biological control agents against this beetle pest. The introductions provided an opportunity to study these two pentatomid predators under Ukrainian conditions. Studies on the biology, population dynamic and host–pest interaction were initiated with *Perillus bioculatus* in western Ukraine [32–35] which showed that embryonic development continued up to 14 days and the optimal temperature for hatching was 25–30°C. Fecundity also depends on temperature with females laying an average of 350 eggs at 30°C, 214 eggs at 25°C, and 43 eggs at 32°C. The high predatory potential of *P. bioculatus* can be explained by its enormous feeding rate as it feeds on nearly all stages of the beetle. However, feeding on the adult beetle pests appears to be uncommon and restricted primarily to the adult predator. A single nymph predator may consume up to 268 eggs. Survival of *P. bioculatus* instars also depends on the host stage. That is, 72% of the last instars survived when fed only on eggs, 36% on host larvae, and only 24% on adults. Fecundity of the adult predators depends on the host stage they consumed. Thus, predaceous females feeding on beetle eggs, larvae, or adults have a fecundity of 490, 208.5, and 161 eggs per female, respectively. In southwestern Ukraine, this predator has 2–3 generations/year, and its fecundity under natural conditions during the summer approximates to what has been observed in the laboratory. In addition, several studies have shown that the most critical issue for establishment of *P. bioculatus* is overwintering, and specifically its ability to hibernate in colder areas of Ukraine. Up to 70% of the predators can hibernate in an unheated laboratory, whereas in the field, 20–25% could hibernate successfully in the forest litter, and only 5–7% could do so in orchards and gardens [36–41].

Podisus maculiventris has been introduced not only to Ukraine, but also to Russia, Moldova and some other countries of the Former Soviet Union [42]. This predator can be reared on a number of hosts including *Galleria mellonella* (L). and *Anagasta kuehniella* (Zeller) [*Ephestia kuehniella*] (Lep., Pyralidae), *Musca domestica* L. (Dipt., Muscidae), and *Sitotroga cerealella* (Olivier) (Lep., Gelechiidae) [43], and on artificial media [44–50]. Furthermore, laboratory colonies of this predator have been maintained successfully for many years [29]. Studies on its field release and establishment have been carried out since 1974. The high efficiency of this predator was observed when it was released in the field at a predator–prey ratio of 1:5. In Moldova, releases of 2nd and 3rd instars of *P. maculiventris* at a predator–prey ratio of 1:10 to 1:30 reduced the numbers of Colorado potato beetle by 60–80% with a significant yield increase to 14 800 kg/ha in experimental treatments versus 6580 kg/ha in the controls [42]. Inundative releases of this predator in southern Russia at a rate of 100 000 predators per hectare provided 91–100% efficacy [51, 52]. Very good results were also obtained in Moldova with field releases of *Perillus bioculatus* in experimental plots of egg plants [aubergines] and potatoes. Despite some successful projects which were conducted in the warm regions of Moldova and southern Russia, attempts to establish *P. bioculatus* and *Podisus maculiventris* as classical biological control agents in the colder areas of Ukraine have proven to be unsuccessful because of limitations in their ability to overwinter and difficulties in getting the agents established in agricultural fields [52]. Currently, the Colorado potato beetle is not under biological control, but studies on its natural enemies are still being conducted to determine whether they can be established in Ukraine. It was shown recently that *P. maculiventris* has a high efficiency against lepidopteran species and can be used in IPM programmes to control pests from that family [53].

Conservation and enhancement

Apple orchards

A diverse community of arthropod pests is associated with apple orchards. Fifty economically important pests of apple occur in orchards within the different regions in Ukraine. Tortricid moths including *Archips* spp., *Pandemis cerasana* (Hübner), *Adoxophyes orana* (Fischer von Röslerstamm), *Hedya nubiferana* (Haworth) [*H. dimidioalba* Retzius], *Ancylis achatana* Denis & Schiffermüller and codling moth (*Cydia pomonella*), aphids, spider mites, apple blossom weevil (*Anthonomus pomorum* (L.); Col., Curculionidae) and apple sawfly (*Hoplocampa testudinea* (Klug); Hym., Tenthredinidae) are the most common pests [54]. Most pest species are sensitive to insecticides and can be eliminated with a single pesticide application. Other species, especially the codling moth and the apple blossom weevil, have developed resistance to organophosphates and pyrethroid pesticides [55]. Fortunately, apple orchards are excellent habitats that provide refuge for a wide range of natural enemies, including parasitoids, microbial pathogens and nematodes [56]. In Ukraine, 1110 species of entomophagous insects, including about 600 species of parasitoids and 500 predators, have been recorded from unsprayed apple orchards [57, 58]. These natural enemies can play an important role in reducing pest numbers in the orchards [59–61].

Research has shown that in apple orchards not treated with pesticides, predatory mites attain high populations and can control the phytophagous mite populations below their economic injury level. However, the application of insecticides in these same orchards resulted in phytophagous spider mite numbers tripling, and under this situation, the predatory mites cannot control them [59–61].

Parasitoids are the largest and most important group of natural enemies of apple pests. Most of the parasitoids belong to the Hymenoptera. Some 50 parasitoids, mainly Hymenoptera and a few Diptera, attack various stages of the tortricid moths in temperate Europe and 30 species have been recorded in Ukraine [60, 61]. They can have significant impacts on the pest resulting in population reduction.

One of the most damaging pests of apples is the codling moth. Parasitoid research on this moth has been undertaken primarily during the past 40 years. Twenty-six entomophagous insects of codling moth have been recorded from Ukrainian orchards and the level of parasitism by various parasitoids varies from 3.5 to 9.3%. The most common parasitoids of the codling moth are *Neoplectops pomonellae* (Schnabl & Mokrzecki) (Dipt., Tachinidae), *Microdus rufipes* Nees [*Bassus rufipes*] and *Ascogaster quadridentatus* Wesmael (Hym., Braconidae), *Pristomerus vulnerator* (Panzer), *Pimpla turionella* L. [*P. contemplator* (O. F. Müller)] and *Trichomma enecator* (Rossi) (Hym., Ichneumonidae), and *Trichogramma embryophagum* (Hartig) (Hym., Trichogrammatidae). Data about the biology, host range and potential for their use against the codling moth have been obtained [54–56].

Eighty species of parasitoids belonging to the Hymenoptera and 16 species belonging to the Diptera have been recorded from the apple moth, *Yponomeuta malinellus* Zeller (Lep., Yponomeutidae) and 56 species are parasitoids of the gypsy moth, *Lymantria dispar* (L.) (Lep., Lymantriidae) [55]. For the gypsy moth, the egg parasitoid, *Anastatus japonicus* Ashmead (Hym., Eupelmidae) has been recorded, while the larval parasitoids include *Apanteles liparidis* (Bouché) [*Glyptapanteles liparidis*], *A. solitarius* (Ratzeburg) and *A. porthetria* (Muesebeck) [*Glyptapanteles porthetriae*] (Hym., Braconidae). In addition, more than 100 natural enemies of the tent caterpillar, *Malacosoma neustria* (L.) (Lep., Lasiocampidae), have been identified including *Telenomus laeviusculus* (Ratzeburg) (Hym., Scelionidae), *Ooencyrtus tardus* (Ratzeburg) (Hym., Encyrtidae), and *A. liparidis* [3].

A conservation and enhancement programme showed that flowering plants attracted a large number of natural enemies of foliage-feeding lepidopteran pests. Thus, flowering plants enhanced the numbers of *Phryxe vulgaris* (Fallén) and *Compsilura concinnata* (Meigen) (Dipt., Tachinidae), and *Apechthis compunctor* (L.) and *Pimpla instigator* (F.) [*P. hypochondriaca* (Retzius)] (Hym., Ichneumonidae). Tkachev reported that between 52 and 90% of *Aporia crataegi* (L.) (Lep., Pieridae] larvae were attacked by these parasitoids [3, 55].

Several predacious mites have been recorded attacking the European red mite, *Panonychus ulmi* (Koch), the two-spotted spider mite *Tetranychus urticae* Koch, and *Amphitetranychus viennensis* (Zacher) (Acari, Tetranychidae) [62]. Of 100 phytoseiid predators, there are 30 species in the apple orchards of which 5–6 species are most common. Predatory mites play an important role in decreasing phytophagous mite populations. Some excellent laboratory and fields studies have been conducted on *Typhlodromus aberrans* Oudemans [*Kampimodromus aberrans*] (Acari, Phytoseiidae) as a predator of the apple rust mite (*Aculus schlechtendali* (Nalepa); Acari, Eriophyidae). These studies described the basic biology, distribution, ecology, feeding behaviour, and fluctuations in populations of the phytoseiid in apple orchards. The population of the phytophagous mites can be controlled at or near the economic threshold level when the ratio between predators such as *Typhlodromus* spp., *Amblyseius* spp. and *Metaseiulus* spp. and the prey is 1 : 50 [62–64].

Cereals

Cereal crops are attacked by several pest species such as cereal flies (Dipt., Cecidomyiidae, Chloropidae), white grubs (Col., Scarabaeidae), click beetles (Col., Elateridae), cutworms (Lep., Noctuidae), flea beetles (Col., Chrysomelidae), stink bugs (Hem., Scutelleridae), thrips

Table 2 Natural enemies of aphids on cereals in Ukraine

Order	Family	Number of species	Some natural enemy species
Coleoptera	Coccinellidae	15	*Propylea 14-punctata* (L.), *Coccinella 5-punctata* L., *C. 7-punctata* L., *Adonia variegata* (Goeze) [*Hippodamia variegata*], *Hippodamia 13-punctata* (L.)
	Melyridae	Several species	*Malachius viridis* F., *M. veneus* (L.)
Diptera	Cecidomyiidae	1	*Aphidoletes aphidimyza* (Rondani)
	Chamaemyiidae	1	*Leucopis glyphinivora* Tanasiichuk
	Syrphidae	7	*Syrphus ribesii* (L.), *Metasyrphus corollae* (F.) [*Eupeodes corollae*], *Episyrphus balteatus* (De Geer)
Hymenoptera	Aphelinidae	Several species	*Aphelinus humilis* Mercet [*A. abdominalis* Dalman], *A. flavipes* (Förster)
	Aphidiidae	8	*Aphidius ervi* Haliday, *A. picipes* (Nees), *Praon volucre* (Haliday)
Neuroptera	Chrysopidae	Several species	*Chrysopa carnea* Stephens [*Chrysoperla carnea*], *Chrysopa perla* Harris [*Chrysoperla harrisii* (Fitch)], *Chrysopa formosa* (Brauer)

(Thysan., Phleothripidae) and aphids (Hem., Aphididae). In examining the aphid pests, there are at least 12 species that attack cereals with the most common ones being *Sitobion avenae* (F.), *Schizaphis graminum* (Rondani), *Brachycolus noxius* Mordvilko [*Diuraphis noxia*] and *Rhopalosiphum padi* (L.). In Ukraine, aphids may have 10–15 generations during the growing season, and during outbreak years they can reduce yield by 10–15%. The economic threshold for aphids is 10–15 individuals per plant. Fortunately, aphids are hosts to a wide range of natural enemies in the Former Soviet Union. More than 70 specialized and 60 polyphagous species have been reported to feed on aphids [65–69]. The main natural enemies attacking aphids are given in Table 2.

In addition, 16 species of spiders in the families Araneidae, Salticidae, and Linyphiidae, and seven species of Entomophthorales fungi are known to attack aphids. If the ratio between aphids and predators or parasitoids is at 20:1 or if 50% of the aphids in a colony are infected by fungi, there is no need to apply chemical insecticides. To enhance aphid predators and parasitoids, it is necessary to use 'wild insectaries' which provide plant diversity. These wild insectaries, for example planting rape with winter wheat, significantly increased the number of aphids parasitized [3].

Augmentation in greenhouses

Greenhouses provide an excellent environment for inoculative or inundative releases of predators or parasitoids. Accordingly, biocontrol of pests in greenhouses was initiated in 1963 when the predatory phytoseiid mite, *Phytoseiulus persimilis* Athias-Henriot (Acari, Phytoseiidae) from Canada was inoculatively introduced to control the spider mite, *Tetranychus urticae*, in cucumber and tomatoes [70–72] providing season long control. These results encouraged both fundamental and applied research on *P. persimilis* for intensive use in greenhouses. Fundamental research included the taxonomy [73, 74], functional morphology, ecology (with particular reference to levels of predation, fecundity, population dynamics and growth), inter-specific interactions, and geographical distribution [74, 75].

On the applied aspect, a number of studies have been conducted on rearing and to develop practical recommendations for releasing *P. persimilis* in greenhouses against the spider mite. Greenhouse and laboratory studies have covered daily activity, fecundity, behaviour, feeding on different diets, and fluctuations in population densities [76–88]. Since the first introduction of this predatory mite, different types of biocontrol agents, notably *Encarsia formosa* Gahan (Hym., Aphelinidae) for control of *Trialeurodes vaporariorum* (Westwood) (Hem., Aleyrodidae), have been studied, and biocontrol and IPM programmes have become common practice in Ukrainian greenhouses. Moreover, a number of published articles on the inoculative and inundative use of natural enemies in greenhouses demonstrate their efficacy against key pests such as aphids and whiteflies [89–101]. In most cases, the natural enemies are either available commercially or produced in small insectaries and microbiological farms which are associated with the greenhouses and used for augmentative releases (Table 3).

Unfortunately, during the past 10 years, the use of biocontrol agents in greenhouses has decreased significantly in Ukraine. In part, the reduction in biological control programmes has been due to the increasing cost of heating greenhouses, which has resulted in a decline in vegetable production. Since the agricultural sector lost the subsidies that helped alleviate the high cost of energy for heating the greenhouses, the profit from this type of production has been low or non-existent. Nonetheless, the total area of greenhouses still in production is large, consisting of 3000 ha, and private rather than public ownership may bring the possibility of reintroducing

Table 3 Beneficial organisms used on cucumbers and tomatoes against pests and diseases in the greenhouse

Beneficial organism (Order, Family)	Pest species controlled (Order, Family)	References
Phytoseiulus persimilis Athias-Henriot (Acari, Phytoseiidae)	*Tetranychus urticae* Koch (Acari, Tetranychidae)	[67, 68, 70, 76, 80–82]
Aphidoletes aphidimyza (Rondani) (Dipt., Cecidomyidae)	*Myzus persicae* Sulzer, *Aphis gossypii* Glover (Hem., Aphididae)	[83, 84, 87, 89, 90]
Encarsia formosa Gahan (Hym., Aphelinidae), *Macrolophus nubilus* (Herrich-Schäffer) (Hem., Miridae), *Aschersonia placenta* Berk. & Broome (Hypocreales, Clavicipitaceae), *Lecanicillium lecanii* (Zimm.) Zare & W. Gams (Hypocreales, Clavicipitaceae)	*Trialeurodes vaporariorum* (Westwood) (Hem., Aleyrodidae)	[3, 86–88, 90, 95–98]
Trichoderma lignorum (Tode) Harz [*T. viride* Pers.] (Hypocreales, Hypocreaceae)	Soil-borne diseases	[98, 99]

Table 4 Efficacy of IPM approaches in cucumber and tomato production in the greenhouses as presented by Lisovyii [102]

Crop	Crop protection system	Components of crop protection system	Yield (kg/m^2)	Yield addition (kg/m^2)	Cost of crop production (US\$/m^2)	Cost of yield addition (US\$/m^2)
Cucumber	Conventional system[1]	*Trichoderma* spp., *Phytoseiulus* spp., *Amblyseius cucumeris* (Oudemans) [*Neoseiulus cucumeris*] Spraying[2]: Fungicides 3–5 Insecticides 2–3 Acaricides 2	18.0	–	4.9	–
	IPM with maximum use of biocontrol	*Trichoderma* spp., *Phytoseiulus* spp., *Macrolophus* spp. Spraying[2]: Fungicides 2	24.0	6	6.5	1.7
Tomato	Conventional system[1]	*Trichoderma* spp., *Amblyseiulus* spp., *Aphidius matricariae* Haliday Spraying[2]: Fungicides 3–5 Insecticides 1–2 Acaricides 1–2	24.2	–	7.9	–
	IPM with maximum use of biocontrol	*Trichoderma* spp., *Phytoseiulus* spp., *Macrolophus* spp. Spraying[2]: Fungicides 3	29.4	5.4	9.6	1.8

[1]Conventional system – based predominantly on pesticide use.
[2]Spray frequency per growing season.

biocontrol programmes into greenhouse production schemes [102].

IPM in greenhouses

As discussed above, biological control agents are often used in greenhouses, but usually more than one control tactic is needed to control a pest. For example, several studies have shown the high resistance of phytoseiids to insecticides [103, 104]. Such compatibility may lead to reduced pesticide usage with increased predator activity. Table 4 shows how various control tactics are integrated in cucumber and tomato production.

Pathogens in biological control

Various pathogens have been used widely in biological control of pests in Ukraine since the 1990s (Table 5). Historically, insect pathogens have played a significant role in biological control in the country (i.e. Metchnikoff's experiments). Therefore, it is not surprising that insect pathogens continue to be an attractive alternative to chemical pesticides.

Codling moth and pathogens

Codling moth, *Cydia pomonella*, is commonly infected by naturally occurring entomopathogenic bacteria, fungi,

Table 5 Microbiological pesticide products used in Ukraine

TAXONOMIC GROUP Genus/Species	ORDER Family *Target species*	Crop
BACTERIA		
Bacillus thuringiensis[1] Berliner (*Bt*)	LEPIDOPTERA	
	Pyralidae	
	Pyrausta sticticalis (L.) [*Loxostege sticticalis*][2, 3]	Sugar beet, alfalfa, sunflower
	Zophodia convolutella (Denis & Schiffermüller)[4]	Berries, grape
	Noctuidae	
	Mamestra brassicae (L.)[3, 4, 5]	Vegetables
	Arctiidae	
	Hyphantria cunea Drury[3]	Apple
	Lymantriidae	
	Euproctis chrysorrhoea L. [*Sphrageidus similis* Fuessly][5]	Forestry
	Lymantria dispar (L.)[4]	Apple
	Geometridae	
	Operophtera brumata (L.)[3]	Forestry
	Abraxas grossulariata (L.)[4]	Berries, grape
	Pieridae	
	Pieris rapae (L.)[3, 4]	Cabbage
	Aporia crataegi (L.)[4]	Apple
	Plutellidae	
	Plutella maculipennis (Curtis) [*P. xylostella* (L.)][4]	Cabbage
	Yponomeutidae	
	Yponomeuta malinellus Zeller[4]	Apple
	Lasiocampidae	
	Malacosoma neustria (L.)[4]	Apple
	COLEOPTERA	
	Chrysomelidae	
	Leptinotarsa decemlineata (Say)[3, 6]	Potato, tomato, aubergine
	Curculionidae	
	Anthonomus pomorum (L.)[3]	Apple
	DIPTERA	
	Culicidae	
	Mosquito species[7]	Aquatic systems
FUNGI		
Beauveria bassiana (Bals.-Criv.) Vuille.	LEPIDOPTERA	
	Tortricidae	
	Cydia pomonella (L.)	Apple
	COLOPTERA	
	Chrysomelidae	
	Leptinotarsa decemlineata	Potato
	HEMIPTERA	
	Aleyrodidae	
	Trialeurodes spp.	Cucumber in greenhouse
	Trialeurodes vaporariorum (Westwood)	Cucumber in greenhouse
	THYSANOPTERA	
	Thripidae	
	Thrips tabaci Lindeman	Cucumber in greenhouse
Metarhizium anisopliae (Metschn.) Sorokïn	COLEOPTERA	
	Elateridae	
	Agriotes spp.	Field crop
Lecanicillium lecanii (Zimm.) Zare & W. Gams	HEMIPTERA	
	Aleyrodidae	
	Trialeurodes vaporariorum	Cucumber in greenhouse
Aschersonia placenta Berk. & Broome	HEMIPTERA	
	Aleyrodidae	
	Trialeurodes vaporariorum	Cucumber in greenhouse
BACULOVIRUSES		
Granulovirus[8]	LEPIDOPTERA	
	Tortricidae	
	Cydia pomonella	Apple

Table 5 (Cont.)

TAXONOMIC GROUP Genus/Species	ORDER Family *Target species*	Crop
Granulovirus (Cont.)	LEPIDOPTERA (Cont.)	
	Noctuidae	
	Agrotis segetum (Denis & Schiffermüller)	Vegetables
	Arctiidae	
	Hyphantria cunea	Apple
Nucleopolyhedrovirus[9]	LEPIDOPTERA	
	Noctuidae	
	Mamestra brassicae	Cabbage
	Heliothis armigera (Hübner)	Tomato
	Lymantriidae	
	Lymantria dispar	Apple
	Arctiidae	
	Hyphantria cunea	Apple

[1]Different varieties of *Bt* are used against different pests and these are footnoted with each target species.
[2]*Bt* var. *galleriae*.
[3]*Bt* var. *thuringiensis* (includes isolates 5072, 4067).
[4]*Bt* var. *kurstaki*.
[5]*Bt* var. *insectus*.
[6]*Bt* var. *tenebrionis* (includes isolate B-125).
[7]*Bt* var. *israelensis*.
[8]The granuloviruses tend to be host specific and each granulovirus was isolated from its respective host.
[9]The nucleopolyhedroviruses tend to be host specific and each nucleopolyhedrovirus was isolated from its respective host.

viruses, and protozoa. The role of entomopathogens in decreasing codling moth populations and the use of microbial pesticides in apple orchards have been intensely studied [105–111]. In particular, the granulovirus of the codling moth (CpGV) is commonly found in populations and can reduce the fecundity and longevity of the adults. The CpGV was isolated from dead overwintering codling moth larvae collected in Russia in the 1940s. Since that time, its biology, virulence, and diversity have been studied, and it has been evaluated as a bioinsecticide in apple orchards [112–118]. Furthermore, the use of microbial products in apple orchards against the codling moth and other lepidopteran species, separately or in combination with inundative releases of *Trichogramma* species, has shown high efficacy and IPM programmes have been successfully established in apple orchards [119, 120].

Another insect pathogen that has received a lot of attention for codling moth control is the fungus, *Beauveria bassiana*. It is one of the most common fungal species infecting codling moth in nature [121–128]. However, its use as a microbial insecticide has been limited because of the lack of humid, warm conditions required for infection. In spite of some limitations of microbial agents, commercially products based on CpGV, *Bacillus thuringiensis* Berliner and *Beauveria bassiana* have been developed and these pathogens are registered for use in apple orchards [129–145].

A fourth pathogen that may have use as a bioinsecticide is the entomopathogenic nematode, *Steinernema carpocapsae* (Weiser) Wouts, Mracek, Gerdin & Bedding (syn. *Neoaplectana carpocapsae*) (Rhabditida, Steinernematidae). It has been recorded from natural populations of the codling moth in many countries of the Former Soviet Union, and there are fragmented data about its natural occurrence in Ukraine [146].

The codling moth is used here as an example of how a fungus, a virus, and a bacterium can be used for pest suppression. In fact, insect pathogens are used inundatively in many cropping systems with bacterial pathogens being the most important in Ukraine for insect suppression (Table 5). At least five varieties of *Bacillus thuringiensis* are being used against lepidopteran and coleopteran species in various cropping systems and one variety is being applied against mosquito species. Entomopathogenic fungal-based products, such as *Beauveria bassiana, Metarhizium anispoliae*, and *Lecanicillium lecanii* (Zimm.) Zare & W. Gams (syn. *Verticillium lecanii* (Zimm.) Viégas) (Hypocreales, Clavicipitaceae) have also been used in greenhouses, field crops and vegetable crops to control pests. Baculoviruses (nucleopolyhedroviruses and granuloviruses) are not extensively used because of their narrow host range and relatively slow speed of kill, and the technical and economic difficulties in producing them *in vitro*. The one exception is the granulovirus of the codling moth which has been produced *in vivo* and is economical to use.

When using insect pathogens, their virulence must be maintained. In addition, the appropriate application rate for a given pest must be known. In most cases, specific application rates have been developed for each pathogen and insect stage. Microbiological pesticides are usually used against the early larval stages (1st- to 3rd-instar larvae) with rates of 1–5 kg/ha (10^8–10^9 *Bacillus thuringiensis*/ha) for bacterial pathogens and against 2nd- and 3rd-instar larvae with rates of 0.1–0.3 kg or litres per hectare (1×10^9–3×10^{11} granules or polyhedral bodies per hectare) for viral formulations. Usually 1–2 applications are recommended with 2- to 8-day intervals against each pest generation. Entomopathogenic fungi are used at different rates depending on species. For example, *M. anisopliae* is usually applied at 10^{12} conidia/ha, *L. lecanii* at 10^{11}–10^{12} conidia/ha, and *Beauveria bassiana* at 10^{11}–10^{12} conidia/ha [3].

Nematodes

Entomopathogenic nematodes in the genera *Steinernema* and *Heterorhabditis* (Rhabditida, Steinernematidae and Heterorhabditidae, respectively) represent a most promising group of pathogens that are lethal to many soil-inhabiting insects [147–149]. They are distributed worldwide and have been found on every inhabited continent and many islands [150]. Both genera have been found in Ukraine (T. R. Stefanovska, unpublished data).

Researchers in many countries have shown great interest in using these nematodes for suppression of soil insect pests [151–159]. Since the early 1980s, more than 100 laboratories in over 50 countries have been conducting research on entomopathogenic nematodes [159] including some countries that neighbour Ukraine. For example, Hungary [160, 161], Poland [162], Czech Republic [163], Slovakia [164], and Turkey [165, 166] have research programmes on these nematodes. In Russia, fundamental research on taxonomy, biology, and practical application of entomopathogenic nematodes has been conducted since the late 1960s [167–175]. Ukraine, however, has lagged behind in fundamental and applied studies on these biological control agents. The most studied nematode group associated with insects is the family Mermithidae [176]. Nonetheless, there has been some interest in Ukraine as demonstrated by work on *S. carpocapsae* to control the codling moth larvae [3]. Fragmented data about the natural occurrence of these nematodes and their biology, ecology and host range and the effectiveness of the *S. carpocapsae* Agriotes strain against lepidopteran and coleopteran pests are available [177, 178]. Recently, *Heterorhabditis* spp. were extracted from soils in the Central Forest steppe areas of Ukraine (T. R. Stefanovska, H. K. Kaya, unpublished data).

Biological control and Ukrainian economy

Biological control has been practised in the Ukraine for many years, but not consistently. In part, the discontinuous use of biological control has been due to the Ukrainian economy. Currently, the Ukrainian agricultural sector is shifting from a command economy to a market economy. The command economy relied on both biological control agents and chemical pesticides. In this economy, the farm supervisors dictated the use of biological control agents or chemical pesticides depending on the pest population density. Because biological control agents were being used, the growers in the command economy were familiar with the various biological control products. The market economy, however, is profit driven, and the farmers rely primarily on chemical control and, therefore, biological control is used minimally or not at all. Although Ukraine has had a rich past in biological control, the farmers in the market economy need to be educated in biological control and IPM approaches. The state government must develop appropriate policy to encourage the use of biological control and IPM approaches. The consumer must also be educated on biological control, and the problems of chemical pesticide usage.

Conclusions and prospects

To further foster biological control in Ukraine, commercially produced natural enemies (predators, parasitoids and pathogens) must be readily available to farmers at a reasonable cost. Previously, the majority of commercial producers of microbial control agents at affordable prices were located outside Ukraine when it was part of the Soviet Union. Following the collapse of the Soviet Union, production of biocontrol products in the countries of the Former Soviet Union declined significantly, and it was not feasible for Ukrainian farmers to buy these products and remain profitable. In some cases, farmers are not aware of biological control agents because they are not commercially available, and companies that sell chemical pesticides often are not interested in introducing biocontrol products. Under these constraints, perhaps the best way to (re)introduce biocontrol products is through local production and demonstration of their successful application in Ukraine. Thus, research must demonstrate that these biological control agents can be efficacious. Issues such as timing of natural enemy release (either inundatively or inoculatively), pest and natural enemy densities, cropping systems, plant diversity, cultural techniques, integration with chemical pesticides, demonstration plots, education programmes for users and consumers, etc., need to be addressed. IPM approaches should use biological control as a cornerstone of control tactics.

Ukraine needs to take all possible steps to reinitiate the ‘era of biocontrol’. It must train scientists who will further advance biological control and take the technology to the commercial companies for production and farmers for implementation. The scientists must then train other individuals (e.g. farm advisors) who will teach farmers about biological control through demonstration plots and workshops on the use and application of biological control agents. Ukraine has the potential to be a major player in organic farming and export of organically grown products to Europe, where the demand for such products is high. Without biological control, the organic market will not flourish.

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References

1. DeBach P. The scope of biological control. In: DeBach P, editor. Biological Control of Insect Pests and Weeds. Reinhold Publishing Corporation, New York, USA; 1964. p. 3–20.
2. Bondarenko NV. Biological Crop Protection. Kolos Publishing, Leningrad; 1978. p. 255 [In Russian].
3. Dyadechko NP, Padiy MM, Shelestova V, Baranovskiy MM, Cherniy AM, Degtyariov BG. Biological Crop Protection. Bila Publishing, Bila Tzerkva, Ukraine; 2001. p. 311 [In Russian].
4. Steinhaus EA. Principles of Insect Pathology. McGraw-Hill Book Company, New York; 1949. p. 757.
5. Krassilstschik IM. De insectorum morbis qui fungis parasitis efficiuntur. Mémoires de la Société des Naturalistes de la Nouvelle Russie, Odessa; 1886. p. 97 [In French].
6. Pospelov VP. Microbiological Methods of Pest Control. VASHNIL, Moscow; 1933. p. 250 [In Russian].
7. Pospelov VP. Perspectives on microbiological methods to control pests. Zapiski Leningradskogo Sel'skokho-zvaistyennogo Instituta 1939;1:205–6 [In Russian].
8. Pospelov VP. Microbiological methods of pest control. Doklady VASHNIL 1944;7:3–8 [In Russian].
9. Telenga NA. New actual problems of biological methods of controlling agricultural and forest pests. In biological methods of pest control. Kiev USHA 1959;1:147–58 [In Russian].
10. Pristavko VP. Microbiological foundation for using fungi formulation together with small doses of insecticides to control Colorado potato larvae. Avtoreferat dissertasii Kandidat biologicheskih Nauk Kiev [PhD thesis]. 1964. p. 18 [In Russian].
11. Telenga NA. Main guidelines for using entomophages for biological methods of pest control and their theoretical foundation. Nauchnie Trudy Instituta Entomologii i Phytopathologii Kiev. AN USSR Publishing 1950;2:12–41 [In Russian].
12. Telenga NA. Experimental research on the role which entomophagous play in insect massive outbreaks. Nauchnie Trudy Instituta Entomologii i Phytopathologii Kiev. AN USSR Publishing 1950;2:42–141 [In Russian].
13. Telenga NA, Tron MM. Microbiological agents for suppression of mass outbreaks of pests. Zashchita Rastenii ot Vreditelei i Boleznei 1966;(1):48–59 [In Russian].
14. Telenga NA. The main results of research and practical use of entomophages to control pests and weeds in Ukraine. In: Plant Protection. Urozay Publishing, Kiev; 1967 [In Russian].
15. Victorov GA. Problems of Population Dynamics Based on the Example of Stink Bugs. Nauka Publishing, Moskow; 1967 [In Russian].
16. Shelestova VS, Padiy MM, Goncharenko OI, Kolisnichenko VS. Biological control. Zakhist Roslin 1999;(10):2–5 [In Ukrainian].
17. Fedorenko VP, Drozda VF. Biocontrol is a common important issue. Zakhist Roslin 2003;(7):3–6 [In Ukrainian].
18. Fadeev YuN, Izhevskii SS. Introduction of useful organisms. Zashchita Rastenii 1981;(7):18–9 [In Russian].
19. Izhevskii SS. Introduction and Utilization of Entomophages. Agropromizdat Publishing, Moscow; 1990. p. 223 [In Russian].
20. Izhevskii SS. Classical biological control: achievements and challenges. Zashchita Rastenii 1990;(1):10–2 [In Russian].
21. Meyer NF. Biological Methods for Controlling Pests. Selhozizdat Publishing, Moscow; 1937. p. 200 [In Russian].
22. Alekseev YaA. Apple Orchard Protection from Woolly Apple Aphid. Krasnodarskoe Knizhnoe Izdatelstvo Publishing, Krasnodar, USSR; 1961. p. 120 [In Russian].
23. Krilova AS. Woolly apple aphid and its control. Nauchnye Trudy Krimskoi Opjtnoi Stantcii Sadovodstva 1962;5:141–2 [In Russian].
24. Yegorov M. There is a way to combat woolly apple aphid. Vinogradorstvo i Sadovodstvo Krima 1962;11:39–40 [In Russian].
25. Vasiliev VP (editor). Agricultural and Forest Pests. Harmful Arthropods and Vertebrates, Volume 2. Urozay Publishing, Kiev; 1988. p. 574 [In Russian].
26. Harcourt DG. Population dynamics of *Leptinotarsa decemlineata* Say in eastern Ontario. Canadian Entomologist 1971;103:1049–61.
27. Ferro DN, Logan RH, Elkinton JS. Colorado potato beetle (*Coleoptera Chrysomelidae*) temperature-dependent growth and feeding rates. Environmental Entomology 1985;14: 343–8.
28. Sanin VA. Small Volume and Ultra Small Volume Spraying. Urozay Publishing, Kiev; 1978. p. 450 [In Russian].
29. Hough-Goldstein JA, Mason HE. Arthropod natural enemies of the Colorado potato beetle. Crop Protection 1993;12: 324–34.
30. Sorokin NS. The Colorado potato beetle *Leptinotarsa decemilineata* Say and its entomopathogens in the Rostov region. Biulleten Vsesovuznyi Nauchno Issledovatel'skii Institut Zashchiky Rastenii; (24):19–24 [In Russian].
31. Gusev GV. Annotated list of Colorado potato beetle entomophages. IOBC/EPRS Information Bulletin 1983;7:6–34 [In Russian].
32. Boiteau G. Control of the Colorado potato beetle: learning from the Soviet experience. Bulletin of the Entomological Society of Canada 1988;20(1):9–14.
33. Starodumova AA. Results on acclimatization of predatory bug *Perillus* in the Lvivska region. Bulletin on Pest Quarantine 1967;19:92–102 [In Russian].
34. Sicura DI. Introduction of the predatory bug *Perillus*. Zashchita Rastenii 1963;(8):45–6 [In Russian].
35. Zayetz YuB. About the biology of *Perillus*. Zashchita Rastenii 1969;(3):53 [In Russian].
36. Shutova NN, Shagov EM, Zayats YuV. Possibilities of overwintering the stink bug *Perillus*. Zashchita Rastenii 1976;(11):50–1 [In Russian].
37. Shagov EM. On the photoperiodic reaction of *Perillus bioculatus* Fabr. (Heteroptera, Pentatomidae). Zoologicheskii Zhurnal 1967;46:948–50 [In Russian].

38. Shagov EM. Preventing the onset of diapause in *Perillus bioculatus* Fabr. (Heteroptera, Pentatomidae) by exposure to artificial long-day conditions. Doklady Akademii Nauk SSSR 1967;174:965–8 [In Russian].

39. Shagov EM. The effect of temperature and humidity on the embryonic development of *Perillus bioculatus* Fabr. (Heteroptera, Pentatomidae). Zoologicheskii Zhurnal 1967;46:1260–2 [In Russian].

40. Shagov EM. The effect of temperature on the predacious bug *Perillus bioculatus* Fabr. (Heteroptera, Pentatomidae). Zoologicheskii Zhurnal 1968;47:563–70 [In Russian].

41. Shagov EM. Some characteristics of the physiology of *Perillus bioculatus* (Heteroptera, Pentatomidae) in the period of winter dormancy. Zoologicheskii Zhurnal 1969;48:827–35 [In Russian].

42. Shagov EM. Photoperiodic reaction of the predatory bug *Perillus* and its variation. Ekologiya 1977;4:96–9 [In Russian].

43. Shagov EM, Chesnek SI. Cold hardiness in the predacious bug *Perillus bioculatus* (Heteroptera, Pentatomidae). Zoologicheskii Zhurnal 1978;57:398–406 [In Russian].

44. Izhevskii SS, Golubeva NN, Buleza VV. Egg parasites of the family Scelionidae as possible parasites of the introduced predacious bug *Podisus maculiventris* (Hemiptera, Pentatomidae). Zoologicheskii Zhurnal 1980;59:73–8 [In Russian].

45. Filipov NA, Braiko YaP, Yarovoi VM, Kirilova GN. Karantinnie vrediteli. I bolezni paslenovikh kultur. Katrya Moldovenyasks Publishing, Kishinev, USSR; 1986. p. 98 [In Russian].

46. Khlistovskii ED, Oleshchenko IN, Shirinyan ZhA, Ismailo VY. Artificial nutrient media for rearing larvae of predatory bugs of the family Pentatomidae. Zoologicheskii Zhurnal 1985;64:117–23 [In Russian].

47. Lipa JI. Progress in biocontrol of the Colorado beetle (*Leptinotarsa decemilineata*) in eastern Europe. EPPO Bulletin/Bulletin OEPP 1985;15:207–11.

48. Shagov EM, Shutova NN. The development of *Podisus* in conditions of constant temperature. Zaschita Rastenii 1977;(4):48–9 [In Russian].

49. Volkovich TA, Saulich AKh. New results in the mass-breeding technology of *Podisus*. Zashchita Rastenii 1992;(10):47–8 [In Russian].

50. Lyashova LV, Ovsyanko NP. Rearing medium for larvae of *Podisus*. Zashchita Rastenii 1985;(1):53 [In Russian].

51. Vlasova VA, Ziskind IA, Izhevskii SS. The possibility of the acclimatization of *Podisus*. Zashchita Rastenii 1980;(4):46–7 [In Russian].

52. Khloptseva RI. The use of entomophages in biological pest control in the USSR. Biocontrol News and Information 1991; 12:243–6.

53. Konverskaya VP, Lemish RP. Predatory stink bug *Podisus* – the new possibilities. In: Abstracts, VI Meeting of Ukrainian Entomological Society, Bila Tzerkva, Ukraine; 2003. p. 51–3 [In Ukrainian].

54. Vasiliev VP, Livschitz IZ. Orchard Pests. Kolos Publishing, Moscow; 1984. p. 399 [In Russian].

55. Tkachev VM, Onischenko LG. Biological Control of Pests and Diseases in Apple Orchards. Urozay Publishing, Kiev; 1986. p. 183 [In Russian].

56. Cross JV, Solomon MG, Blommers L, Campbell CAM, Easterbrook MA, Jay CN, *et al*. Review of biocontrol of pests of apples and pears in northern and central Europe. 2. Parasitoids. Biocontrol Science and Technology 1999;9: 277–313.

57. Tkachev VM. Biocontrol in apple orchards. Zashchita Rastenii 1988;(10):30–2 [In Russian].

58. Zerova MD, Tolkanitz VI, Sviridov SV. Entomophagous Insects of Pests of Apple Orchards in the South-West Region of the Former USSR. Naukova Dumka Publishing, Kiev; 1992. p. 276 [In Russian].

59. Zerova MD, Kotenko VI, Tolkanitz VI, Kononova VM, Tkachev VM, Slovohotov VP. On Biological Antagonism. Urozay Publishing, Kiev; 1988. p. 191 [In Ukrainian].

60. Zerova MD, Kotenko VI, Tolkanitz VI, Seregina LYa. Entomophagous insects of Tortrix viridana *L*. (*Tortricidae*) and Lymantria dispar *L*. (*Lymantriidae*). Naukova Dumka Publishing, Kiev; 1989. p. 198 [In Russian].

61. Melika GG, Zerova MD, Sviridov SV, Krochko VYu, Schoka VV, Babilya EI. Recommendations on collection, identification and application of entomophagous insects of major pests of apple tree orchards in the Zakarpatie District, Ukraine. Department of Entomophagous Insects and Ecological Principles of Biocontrol, Institute of Zoology of National Ukrainian Academy of Sciences, Uzhgorod; 1990. p. 87 [In Russian].

62. Loshitskii VP. Harmful *Tetranychus* spp. mites in fruit orchards in the northern Polissya. *Sadivnitstvo* 1977;25:24–5 [In Russian].

63. Loshitskii VP, Dyadechko NP. Predatory Phytoseiidae mites in Polissa and Forest-Steppe of Ukraine and their role in the population dynamics of *Amphitetranychus viennensis*. In: Zashchita Rastenii ot Vreditelei, Volume 200, Nauchnye Trudi USHA 1977; p. 25–8 [In Russian].

64. Loshitskii VP, Tkachev VM. Phytophagous mites. Methods of population reduction in fruit orchards in Forest-Steppe region and Polissya. Zakhist Roslin 1999;(5):21–3 [In Ukrainian].

65. Berest ZL. Parasites and predators of the aphids *Brachycolus noxius* and *Schizaphis graminum* on crops of barley and wheat in the Nikolaev and Odessa regions. Vestnik Zoologii 1980;(2):80–1 [In Russian].

66. Dyadechko NP. Coccinellidae of Ukrainean SSR. Academia Nauk Publishing, Kiev; 1954. p. 130 [In Russian].

67. Dyadechko NP. Conservation and use of entomopathogens in agricultural ecosystems. Zashchita Rastenii 1978;(2):22–3 [In Russian].

68. Fedorenko VP. Seasonal migration of Coccinellidae. Zakhist Roslin 2003;(5):8–10 [In Ukrainian].

69. Ruban MB, Dyadechko NP. Entomophages of grain aphids. Zashchita Rastenii 1973;(9):30 [In Russian].

70. Beglyarov GA, Vasil'ev RA, Korol' IV, Batov AI, Kokina RV. Biological control of spider mites. Zashchita Rastenii 1968;(13:7):26–9 [In Russian].

71. Bondarenko NV, Kosonogov PA. The large scale release of *Phytoseiulus* in glass frames. Zashchita Rastenii 1970;(15:1):10–1 [In Russian].

72. Bondarenko NV. Certain ecological principles of tetranychid mite control in the USSR. Zeszyty Problemowe Postepow Nauk Rolniczych 1972;129:263–9 [In Russian].

73. Beglyarov GA, Uschekov AT. Ecology of the predatory mite *Phytoseiulus persimilis* and its effectiveness in practical application in the USSR. Zeszyty Problemowe Postepow Nauk Rolniczych 1972;129:9–102 [In Russian].

74. Kolodochka IA, Denmark HA. A new genus of phytoseiid mite (Acari: Phytoseiidae). Journal of the Ukrainian Entomological Society 1993;3–4:9–26 [In Russian].

75. Akimov IA, Zerova MD, Kolodochka LA. Fundamental research on parasitic and predatory arthropods and their role in biocontrol development. Vestnik Zoologii 1977;31(1–2): 5–15 [In Russian].

76. Akimov IA, Kolodochka LA. Ecological foundation for using Phytoseiidae mites. Zashchita Rastenii 1986;(8):20–1 [In Russian].

77. Akimov IA, Kolodochka LA. Biocoenotic principles of ecological plant protection on indoor crops (based on experience of using acariphages). Vestnik Zoologii 1989;(1):3–7 [In Russian].

78. Pogrebnyak SG, Kolodochka LA. Survival of starving phytoseiid mites *Amblyseius longispinosus*. Vestnik Zoologii 1990;(3):45–9 [In Russian].

79. Bondarenko NV. Method of rearing and using *Phytoseiulus*. Zashchita Rastenii 1974;(11):33–5 [In Russian].

80. Osipova NP. The biomethod in glasshouses in Russia. Zashchita Rastenii 1980;(2):36 [In Russian].

81. Dyadechko NP, Tsybul'skaya HM. The use of natural enemies to control pests in Ukraine. Zapiski Leningradskogo Sel'skokhozvaisyennogo Instituta 1971;212:8–10 [In Russian].

82. Beglyarov GA. Biological method of protecting vegetables in greenhouses [dissertation for Doctor of Biological Science]. Golizino, Russia: Vsesoiuzniy Institut Phitopatologii; 1987 [In Russian].

83. Beglyarov GA, Malov NA, Meshkov OI, Chalkov AA, Bondarenko NV. Technology for rearing *Phytoseiulus*. Zashchita Rastenii 1986;(6):28 [In Russian].

84. Chalkov AA, Bondarenko NV. A container for rearing *Phytoseiulus*. Zashchita Rastenii 1987;(2):3–38 [In Russian].

85. Chalkov AA. An appliance for separating *Phytoseiulus* from the plant mass. Zashchita Rastenii 1989;(4):23 [In Russian].

86. Bondarenko NV. In glasshouses – without pesticides. Zashchita Rastenii 1984;(5):13–4 [In Russian].

87. Tsybul'skaya GN, Chizhik RI, Statyanskaya EN. The protection of cucurbits grown under cover. Zashchita Rastenii 1975;(5):25–6 [In Russian].

88. Plotnikov VF, Garkina G, Klimachev MP. Integrated protection of vegetables in winter greenhouses. Zashchita Rastenii 1977;(2):17–20 [In Russian].

89. Popov NA, Tsybul'skaya IA, Bogach GI. *Encarsia* and *Phytoseiulus* in glasshouse conditions. Zashchita Rastenii 1980;(2):35–6 [In Russian].

90. Adashkevich BP, Kadirov AL. Biological protection from white fly. Zashchita Rastenii 1990;(11):35–6 [In Russian].

91. Adashkevich BP, Kadirov AL. Rearing of *Encarsia*. Zashchita Rastenii 1980;(11):23–4 [In Russian].

92. Adashkevich BP. Development of predatory syrphids (Diptera, Syrphidae) during rearing in laboratory conditions. Zoologicheskii Zhurnal 1990;59:133–6 [In Russian].

93. Beglyarov GA, Smetnik AI. Situation and prospects for biological control in protected crops. In: Technical innovation in agriculture and environment, Rome, Italy 1991.

94. Eremenko AP. The biological method in glasshouses. Zashchita Rastenii 1984;(11):18–9 [In Russian].

95. Popov NA, Belousov YuV. Rearing of *Aphidimyza* and *Aphidius*. Zashchita Rastenii 1987;(10):24 [In Russian].

96. Beglyarov GA, Sugalin RA. Methodological Recommendation for Control of *thrips tabaci*. Selhozizdat Publishing, Moscow; 1985. p. 41 [In Russian].

97. Tron' MM, Krizanovska TV, Boyarina VV. Entomophages in green houses. Zashchita Rastenii 1999;(12):9 [In Russian].

98. Krizanovska TV. Use of the predatory bug *Macrolophus* on vegetables in greenhouses. Zakhist Roslin, Bulletin of Scientific Publications 1983;(30):31–4 [In Ukrainian].

99. Boyarin VV, Tron' MM. *Macrolophus*. Interrelation in the trophic I system "Plant-Phytophage-Entomophage" Zakhist Roslin 2003;(10):12–4 [In Ukrainian].

100. Ivanov GM, Mischenko VS. Laboratory cultivation of *Ashersonia*. Zashchita Rastenii 1986;(4):23 [In Russian].

101. Tron' MM, Krizanovska TV. Use of entomophages to control pests in greenhouses. Zakhist i Karantin Roslin 1996;44: 113–36 [In Ukrainian].

102. Lisovyii MP. Main results of research in biological methods of plant protection and prospects of its development in the Ukraine. Archives of Phytopathology and Plant Protection 2002;35:1–6.

103. Golovkina LS, Zereva YF, Aksyutova LN, Petrov VM, Fridrikhson RG, Zinkovskaya GI. Resistant forms of *Phytoseiulus*. Zashchita Rastenii 1989;(8):9–13 [In Russian].

104. Bushchik TN, Lazurina MV. Benlate and *Phytoseiulus*. Zashchita Rastenii 1982;(4):22 [In Russian].

105. Lapa AM, Tkachev VM. Ecological aspects of an integrated pest management system in orchards. Acta Phytopathologica et Entomologica Hungarica 1992;27: 401–3.

106. Pristavko VP, Rezvatova OI. The granulosis of the codling moth. Sel'skogo Khosvaistya Rubenzhom Rastenievod 1971;43–5 [In Russian].

107. Korol'l IT, Kanapatskaya VA. Granulosis of codling moth and possibilities of its use to control pests. Nauchnye Trudy Belorusski NIIZR 1978;8:123–128 [In Russian].

108. Lukyanchikov VP, Kizilova ER. Granulosis virus and the codling moth. Sadovodstvo I Vinogradorstvo 1971;(14) [In Russian].

109. Kizilova ER, Zemlina AG. Effect of temperature on the development of granulosis in caterpillars of *Carpocapsa pomonella* L. Nauchnye Doklady Vysshei Shkoly, Biologicheskie Nauki 1974;8:22–4 [In Russian].

110. Mitrofanov VB. Granulosis virus disease in codling moth *Laspeyresia pomonella*. Biulleten Vsesovuznyi Nauchno Issledovatel'skii Institut Zashchiky Rastenii 1976;(38):11–6 [In Russian].

111. Mitrofanov VB. Effect of higher than optimal temperature on the activation of latent viral infection (granulosis) in codling moth (*Laspeyresia pomonella* L.). Biulleten Vsesovuznyi Nauchno Issledovatel'skii Institut Zashchiky Rastenii 1976;(39):19–22 [In Russian].

112. Atanasov A. Granulosis virus of codling moth. Rastitelna Zashchita 1984;32(9):30–2 [In Bulgarian].

113. Drozda VF, Lappa NV. Structure of codling moth *Laspeyresia pomonella* populations as a result of using biological and chemical preparations. Trudy Latviiskoi Sel'skokhozyaistvennoi Akademii 1979;(176):3–29 [In Russian].

114. Tkachev VM. Bacteria and viruses against the apple worm (*Laspeyresia pomonella*). Zashchita Rastenii 1982;(8):11 [In Russian].

115. Zhyhaiev HN, Symchuk PA. Using microbiological method of controlling codling moth in orchards of southern Ukraine (*Carpocapsa pomonella*). Visnyk Sil'skohospodaskikh Nauk 1971;3:70–3 [In Ukrainian].

116. Tkachev VM. Bacterial-viral mixture to control codling moth. Zashchita Rastenii 1987;(4):32–4 [In Russian].

117. Tkachev VM, Romanova LV. Economic effectiveness of bio-preparations. Zashchita Rastenii 1985;(6):10–2 [In Russian].

118. Goral' VM, Lappa NV. Comparative action of microbial preparations on the codling moth *Laspeyresia pomonella*. Trudy Latviiskoi Sel'skokhozyaistvennoi Akademii Elgava 1979;(176):15–24 [In Russian].

119. Matvievskii AS, Khomenko I, Loshitskii VP. Integrated orchard control. Zashchita Rastenii 1976;(6):24–5 [In Russian].

120. Matvievskii AS. Integrated protection of orchards. Zashchita Rastenii 1979;(6):26–7 [In Russian].

121. Dyadechko NP. The experience of using white muscardine (*Beauveria bassiana* (Bals) Vuill.) to control Colorado potato beetle. Nauchnye Trudy Ukrainskogo NIIZR 1959;221–3 [In Russian].

122. Arkhipova VD. Fungus diseases of codling moth, *Carpocapsa pomonella* L. (Lepidoptera: Tortricidae). Entomological Review 1965;44:48–54 [English translation of Entomologicheskoe Obozreniei 1965;44:89–99] [In Russian].

123. Primak TA. Susceptibility of different stages of codling moth (*Carpocapsa pomonella* L.) to the white muscardine fungus (*Beauveria bassiana* (Bals) Vuill.). Zashchita Rastenii (K 1967;(5):101–9 [In Russian].

124. Koshevskaya NN. The effect of Dipterex and the fungus *Beauveria* on regular elements of hemolymph of *Carpocapsa pomonella*. Zakhyst Roslin 1973;(18):16–21 [In Ukrainian].

125. Karadzhov S. Efficiency of the bio-preparation Beauverin (*Beauveria bassiana* (Bals) Vuill.) in the biological control of apple codling moth (*Carpocapsa pomonella* L). Horticultural and Viticultural Science 1974;11:53–9.

126. Zigaev GN, Primak TA. Efficiency of bio-formulation boverin on white fly larvae. Zaschita Rastenii 1980;(27):90–3 [In Russian].

127. Goral' VM, Lappa NV, Goral' SV. Storage of different formulations based on *Beauveria bassiana* in commercial technologies in biological agriculture. In: Proceedings, International Organization for Biological Control of Noxious Animals and Plants, Conference, Odessa; 1999. p. 43 [In Russian].

128. Drozda VF. The effectiveness of use of Boverin against the pear tortricid. Zakhist Roslin 1978;(24):27–9 [In Ukrainian].

129. Lappa NV, Goral' VM, Guliy VV. Biological Crop Protection in Greenhouses Methodical Recommendations. VASHNIL, Moscow; 1985. p. 91 [In Russian].

130. Fedorinchik NS, Korostel SI. Effect of *Bacillus thuringiensis* on the offspring of codling moth as a result of inoculation of the pest at the larval stage. Sel'skokhozyaistvennaya Biologiya 1972;7:383–7 [In Russian].

131. Lappa NV, Goral' VM, Drozda VF, Krasnickaya PC. Recommendation on Use of Bacterial Formulations to Control Agricultural Pests. Agropromizdat Publishing, Moscow; 1989. p. 43 [In Russian].

132. Lappa NV. Use of Microbiological Method to Control Pests. Tekhnol Priemy Zashchity Rast. na Ukraine, Kiev; 1981. p. 100–7 [In Russian].

133. Goral' VM, Lappa NV. Integrated plant protection in greenhouses. Zashchita Rastenii 1995;(2):6 [In Russian].

134. Babidorich MM, Kita VS, Mazuik VA. Use of viral formulations to control *Hyphantria cunea* Dr. in apple orchards. In: Microbiological Method to Control Pests and Diseases in Apple Orchards. Chitnitza Publishing, Kishinov, USSR; 1989. p. 47–50 [In Russian].

135. Kandybin NV, Stus AA. Efficiency of microbiological formulations to control *Euproctis chrysorrhoea* and *Malocosoma neustria* in Crimea. Trudi Latviĭskoĭ Sel'skokhozyaĭstvennoĭ Akademii 1979;176:39–41 [In Russian].

136. Kandybin NV. Microbial formulations (Bitoxibacillin). Zashchita Rastenii 1991;(8):54–5 [In Russian].

137. Lappa NV, Drozda VF, Goral' VM, Ustimenko AA, Zubarova FP. Effect of bacterial formulations on complex of cabbage pests Zakhist Roslin 1983;(30):11–5 [In Ukrainian].

138. Zurabova EP, Pokoziy IT. Use of lepidocid to control Lepidoptera pests in fruit and berry orchards. Zashchita Rastenii 1986;(5):26–7 [In Russian].

139. Tkachev VM, Matvievskiy AC. Lepidocid to control codling moth. Sadovodstvo 1986;(4):2–23 [In Russian].

140. Kandybin NV, Smirnov OV. Problems and perspective on using *B. thuringiensis* to control mosquitoes and flies. IOBC/EPRS Information Bulletin 1987;21:6–31.

141. Loshitskii VP, Tkachev VM, Shelestova VS, Stefanovska TR. The use of microbiological pesticides and growth regulators for integrated control of *Tortrix* moth in pome fruit orchards. In: Abstracts, 50th International Symposium on Crop Protection, Gent, Belgium, 1998 May 5; 1998. p. 136.

142. Dyadechko NP, Goncharenko OI, Stefanovska TR. Using natural agents for crop protection against pests in Ukraine. In: Abstracts, 50th International Symposium on Crop Protection, Gent, Belgium, 1998 May 5; 1998. p. 137.

143. Shelestova VS, Loshitskii VP, Tkachev VM, Stefanovska TR. Using of Carpovirusin and insect growth regulators to control codling moth and Tortricidae spp. in Forest-Steppe of Ukraine. Naukoviy Visnik National Agricultural University 1998;7:53–9 [In Ukrainian].

144. Stefanovska TR, Shelestova VS, Pidlisnyuk VV, Goncharenko OI. The use of biological control for *Cydia pomonella* L (Lepidoptera: Tortricidae) management in Ukraine. In: Proceedings, California Conference on Biological Control, Riverside, CA, USA, 2000 July 11, 12; 2000. p. 183–7.

145. Stefanovska TR, Tkachev VM, Loshitskii VP. Improved control of pests in pome fruit orchards using natural enemies.

In: Abstracts, 51st International Symposium on Crop Protection, Gent, Belgium, 1998 May 5; 1998. p. 121.

146. Dyadechko NP (editor). Fundamentals of Biological Protection. Urozay Publishing, Kiev; 1990. p. 268 [In Russian].

147. Gaugler R, Kaya HK editor. Entomopathogenic Nematodes in Biological Control. CRC Press, Boca Raton, FL, USA; 1990. p. 365.

148. Kaya HK, Gaugler R. Entomopathogenic nematodes. Annual Review of Entomology 1993;38:181–206.

149. Kaya HK, Stock SP. Techniques in insect nematology. In: Lacey L, editor. Manual of Techniques in Insect Pathology. Academic Press, London; 1997. p. 281–324.

150. Hominick WM. Biogeography. In: Gaugler R, editor. Entomopathogenic Nematology. CABI Publishing, Wallingford, UK; 2002. p. 115–43.

151. Adams BJ, Nguyen KB. Taxonomy and systematics. In: Gaugler R, editor. Entomopathogenic Nematology. CABI Publishing, Wallingford, UK; 2002. p. 1–33.

152. Boemare N. Biology, taxonomy and systematics of *Photorhabdus* and *Xenorhabdus*. In: Gaugler R, editor. Entomopathogenic Nematology. CABI Publishing, Wallingford, UK; 2002. p. 35–56.

153. Stock SP, Griffin CT, Chaenari R. Morphological and molecular characterization of *Steinernema hermaphroditum* n. sp. (Nematoda: Steinernematidae), an entomopathogenic nematode from Indonesia, and its phylogenetic relationship with other closely related taxa. Nematology 2004;6:401–12.

154. Dowds BCA, Peters A. Virulence mechanisms. In: Gaugler R, editor. Entomopathogenic Nematology. CABI Publishing, Wallingford, UK; 2002. p. 79–98.

155. Georgis R, Hague NGM. Nematodes as biological insecticides. Pesticide Outlook 1991;3:29–32.

156. Campbell JF, Lewis EE. Entomopathogenic nematode host-search strategies. In: Lewis EE, Campbell JF, Sukhdeo MVK, editors. The Behavioural Ecology of Parasites. CABI Publishing, Wallingford, UK; 2002. p. 13–38.

157. Kaya HK. Entomopathogenic nematodes and their prospects for biological controls. In: Proceedings, California Conference on Biological Control, Riverside, CA, USA; 2000 July 11–13; 2000. p. 38–48.

158. Kaya HK, Koppenhöfer AM. Biological control of insects and other invertebrates with nematodes. In: Chen ZX, Chen SY, Dickson DW, editors. Nematology – Advances and Perspectives, Volume 2. Tsinghua University Press, Beijing, China; 2004. p. 447–96.

159. Gaugler R, Grewal P, Kaya HK, Smith-Fiola D. Quality assessment of commercially produced entomopathogenic nematodes. Biological Control 2000;17:100–9.

160. Griffin CT, Dix I, Joyce SA, Burnell AM, Downes MJ. Isolation and characterisation of *Heterorhabditis* spp. (Nematoda: Heterhorhabdiridae) from Hungary, Estonia and Denmark. Nematology 1999;1:331–2.

161. Fodor A. Molecular and gnotobiological approach to EPN/EBN co-specialization. In: Abstracts, 3rd International Symposium on EPN and Symbiotic Bacteria, Wooster, OH, USA, 2003 September 4–7; 2003. p. 8–9.

162. Jaworska MM, Dudek, B. A survey of insect parasitic nematodes in the soil of some crops. Zeszyty Naukowe Akademii Rolniczej im. Hugona Kollataja w Krakowie, Ogrodnictwo 1992;20:131–47 [In Polish].

163. Mracek Z, Beevar S, Kindamann P. Survey of entomopathogenic nematode from the families Steinermenatidae and Heterorhabditidae (Nematoda: Rhabditida) in the Czech republic. Folia Parasitologica 1999;46:145–8.

164. Sturhan D, Liskova M. Occurrence and distribution of entomopathogenic nematodes in the Slovak Republic. Nematology 1999;1:273–7.

165. Hazir S, Kaya HK, Stock SP, Keskin, N. Entomopathogenic nematodes (Steinernematidae and Heterorhabditidae) for biological control of soil pests. Turkish Journal of Biology 2003;27(4):181–202.

166. Hazir S, Stock SP, Kaya HK, Koppenhöfer AM, Keskin N. Developmental temperature effects on five geographic isolates of the entomopathogenic nematode *Steinernema feltiae* (Nematoda: Steinernematidae). Journal of Invertebrate Pathology 2001;77:243–50.

167. Rubtzov IA. Harmful Mermithids, Volume 1. Nauka Publishing, Moscow; 1972. p. 1–254 [In Russian].

168. Rubtzov IA, Koval YuV. Mermithids from Colorado potato beetle. Sbornik Trudov VIZR 1975;44:126–53 [In Russian].

169. Shimkina MA. On the mermithid fauna of forest ecosystems of the Steppe zone in Ukraine. In: Sonin MD, editor. Helminths of Insects. Nauka Publishing, Moscow; 1980. p. 153–5 [In Russian].

170. Polozhentzev PA. Entomohelminths. Zashchita Rastenii 1976;(3):44–7 [In Russian].

171. Veremchuk GV, Issi IV. On the development of the microsporidians of insects in the entomopathogenic nematode *Neoplectaba agriotis* Veremchuk (Nematoda: Steinernematidae). Parazitologiya 1970;4:3–7 [In Russian].

172. Danilov LG, Borodavko NP. Use of entomopathogenic nematodes to control root cabbage fly. Zashchita Rastenii ot Vreditelei, Boleznei i Sornyakov 1997;(6):31–6 [In Russian].

173. Spiridonov SE. Entomopathogenic nematodes. Zashchita Rastenii 1987;(6):24–8 [In Russian].

174. Spiridonov SE, Voronov DA. Small scale distribution of *Steinernema feltiae* juveniles in cultivated soil. In: Griffin CT, Gwynn RL, Masson JP, editors. Cost 810 Biotechnology: Ecology and Transmission Strategies of Entomopathogenic Nematodes. Office for Official Publications of the EC, Luxembourg; 1995. p. 36–41.

175. Kandybin NV, Smirnov OV. Problems and perspective on using *B. thuringiensis* to control mosquitoes and flies. IOBC/EPRS Information Bulletin archenko, N.A. Peculiarities of mermithid population dynamics. In: Sonin MD, editor. Helminths of Insects. Nauka Publishing, Moscow; 1980. p. 139–52 [In Russian].

176. Stefanovska TR. Possibilities to use *Steinernema carpocapsae* for control of codling moth in apple orchards. In: Abstracts, 51st International Symposium on Crop Protection, Gent, Belgium, 1998 May; 1998. p. 137.

177. Stefanovska TR, Shelestova VS. Is it possible to use entomopathogenic nematodes in IPM programs in Ukraine. Plant Protection 2001;(11):16–20.

178. Stefanovska TR, Shelestova VS. Entomopathogenic nematodes. Zakhist Roslin 2001;(11):13–4 [In Ukrainian].