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# SPECIFICITIES OF REARING THE LABORATORY POPULATION OF *USCANA SENEX* (GRESE, 1923) AND ITS ADAPTATION POTENTIAL AGAINST *BRUCHUS PISORUM* (LINNAEUS, 1758) IN THE AGROCENOSES OF COMMON PEA

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**The aim of the study** was to evaluate the bioecological properties and reproductive potential of egg parasitoid *Uscana senex* (Grese, 1923) (Hymenoptera: Trichogrammatidae) with the purpose of using it within the programs of biological control over pea weevil *Bruchus pisorum* (Linnaeus, 1758) (Coleoptera: Chrysomelidae). **Methods.** The belonging of a parasite to a particular species was determined by morphological traits and a detailed analysis of the structure of the genitalia and the form of the imago club. Common entomological methods were used in laboratory and field conditions to study the impact of various ratios of parasite:host (from 1:1 to 1:45) on the reproductive characteristics of entomophages. The main viability indices of the laboratory and natural populations of the parasite were compared: motor activity, searching capacity, restoration rate, and the share of deformed insects. The impact of the periodic passage of a laboratory culture via the natural host on the quality of biomaterial was also evaluated. The statistical results were processed by the dispersion analysis (ANOVA), and the data were presented as  $x \pm SD$ . **Results.** The results demonstrated that the fecundity of female entomophages was increasing considerably with the increase in the host number; however, the efficiency of the parasite utilization decreased with the following generations. The highest biological efficiency in field conditions on the plots with Oplot pea cultivar was registered at the 1:5 ratio, where the parasitism rate was 39.8%, and the seed damage was minimal — 5.59%. Statistically significant differences between the native and laboratory populations of *U. senex* were found, and the native population demonstrated higher viability indices as compared to the laboratory population. The periodic passaging of the laboratory population via the natural host partially compensated for the viability loss and reduced reproductive potential. **Conclusions.** The obtained results demonstrated high

efficiency of *Uscana senex* as a biological agent in the integrated systems of protecting pea from *Bruchus pisorum*. It was proven that maintaining the reproductive potential and viability of the parasite was ensured on condition of periodic contacts between the laboratory population and the natural host, and adherence to the optimal parasite:host ratio, which promotes the preservation of stable quality of the biomaterial.

**Keywords:** entomophage, phytophage, laboratory culture of entomophage, biological control, viability, efficiency, grain legumes.

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## INTRODUCTION

In modern conditions of global increase in population numbers, soil deterioration, and climate change, there is a growing need for stable food sources with high nutritional value. It is known that pea, *Pisum sativum* (Linnaeus, 1758) (Fabales: Fabaceae), has a relevant place among legumes due to high protein content (up to 13–38% in grain) (Daba & Morris, 2021), which makes it a promising alternative to animal sources of proteins. In addition, contrary to animal protein, pea cultivation has a considerably smaller ecological footprint, for instance, lower greenhouse gas emissions and less water consumption. It ensures the strategic role of pea in the formation of food safety and sustainable agriculture in the world.

This crop is grown in many developed industrial countries, such as China, India, Canada, the United States of America, and Egypt etc. At the same time, in 2019, according to the database of the Food and Agriculture Organization of the United Nations (FAO), France and Germany were the largest producers of dry peas among European countries (Ambrose et al., 2023). Ultimately, the area under cultivated pea is showing a global upward trend, driven by increased demand for plant protein, the development of the market for alternative food sources, and efforts to reduce the environmental impact of traditional agriculture.

The increase in pea fields in many countries is accompanied not only by agro-economic benefits, but also by many phytosanitary risks. In particular, intensive cultivation of the crop leads to the mass colonization of agrocenoses by harmful phytophages, which can have negative consequences for yield and ecological balance.

In some years, outbreaks of mass reproduction of the pea weevil *Bruchus pisorum* (Linnaeus, 1758) have been registered in pea crops, accompanied by significant crop losses and deterioration in the quality of seed material (Reddy et al., 2018). The infestation of pea seeds by pea weevils varies from 10% to

90%, depending on the region and growing conditions (Voice et al., 2022). The limited effectiveness of modern phytosanitary measures and agrotechnical methods of controlling *B. pisorum* L. has led to increased scientific research aimed at identifying and evaluating promising biological agents and technological solutions for improving integrated plant protection systems against this pest (Bonet et al., 2012; Statkevych & Drozda, 2020).

In particular, there is currently a steadily growing trend towards the study of insects of the genus *Uscana* spp. (Hymenoptera: Trichogrammatidae) — insect egg parasitoids for various families of the order Coleoptera. It is known that the genus *Uscana* spp. comprises 28 species in the world fauna, in particular, the typical species *U. semifumipennis* Gir., widespread in the United States, Mexico, and Guatemala (Fursov, 1995; Pintureau et al., 1999; Pinto, 2006). In Chile, Brazil, and Argentina, *U. espiniae* sp. nov. and *U. chiliensis* Viggiani are widespread (Pintureau et al., 1999). In Europe, such species as *U. olgae* Fursov and *U. senex* Grese are known (Fursov, 1995). Many studies focused on African species, including *U. caryedoni* Viggiani (Delobel, 1989) and *U. lario-phaga* Steffan (Van Alebeek & van Huis, 2007), as well as the Indian species *U. mukerjii* (Mani) (Sood & Pajni, 2006).

A representative of European fauna, the species *U. senex* Grese, is characterized by a high level of trophic specialization concerning *Bruchus loti* Paykull, *Bruchus rufipes* Herbst, *Bruchus lentis* Froggatt, *Caryedon serratus* Olivier and, of course, *Bruchus pisorum* (Linnaeus, 1758) grain beetles (Lesovoy, 2003). Due to its bioecological characteristics, the entomophage is considered a promising agent in biological control programs and can be used in integrated pea protection systems.

It is known that both *U. senex* and representatives of the genus *Trichogramma* spp. are actively used in commercial breeding, and the domestication of *U. senex* Grese is carried out using the eggs of broad-bean seed beetle (*Acanthoscelides obtectus* Say.),

which is convenient for mass rearing of the parasite (Parra, 2014; Bradowsky & Bradowsky, 2022). However, most studies have focused on taxonomy and some aspects of its behavior for the purpose of controlling the pea weevil (Fursov, 1995; Bonet et al., 2012; Bradowsky & Bradowsky, 2022). Currently, the biological characteristics and technological parameters of mass rearing of entomophages remain poorly studied.

Thus, the research on *U. senex* Grese is of great importance given its potential as a biological agent in the fight against harmful phytophages of grain legumes, in particular, the pea weevil. Of particular relevance is the study of the bioecological specificities of the entomophage *U. senex* Grese, in particular, its life cycle, reproductive potential, trophic relations, and ecological plasticity, in order to evaluate its effectiveness as a potential biological agent in regulating the population of pests of grain legumes.

**The aim of the research** was to determine the biological parameters during laboratory rearing of the entomophage *Uscana senex* Grese and its suitability for release into field conditions to protect peas against harmful phytophages.

**MATERIALS AND METHODS**

**1.1. Morphological analysis.** The species affiliation of the parasite was determined based on morphological characteristics and a detailed analysis of the structure of the genitalia and the shape of the imago club (Bonet et al., 2012). For this purpose, adult males and females of *U. senex* Grese were immersed and

fixed in Canadian balsam (Platner, 1998). Measurements were taken of the taxonomic characteristics used to classify species of the Trichogrammatidae family: the shape and size of the antennae club, the venation of the forewings in males and females, and the structure of the male genitalia. All measurements were made in micrometers and corresponded to the maximum length of each morphological structure.

Particular attention was paid to diagnostic differences between males and females, and comparative characteristics with the closely related species *U. espiniae* sp. nov. and *U. caryedoni* Viggiani, 1986 (Hymenoptera: Trichogrammatidae), which allows for precise identification of *U. senex* Grese among related taxa. In summary, it can be noted that *U. senex* Grese demonstrates (Table 1) a set of morphological features that clearly distinguish it from *U. espiniae* sp. nov., in particular, a greater number of sensilla on the first segment of the club (4 vs. 3), an elongated first segment of the club, a shorter radial vein, and more massive genitalia.

**1.2. Laboratory cultivation.** The set of laboratory studies, which envisaged the determination of bioecological indices of *U. senex* Grese, was implemented in 2022–2024. For instance, the parasite rearing was performed using the standard methods modified by us (Wang et al., 2014; Bradowsky V. & Bradowsky N., 2022; Statkevych et al., 2024). The stock culture was formed by catching insects from their natural ecosystems. The entomophages were kept in the climatic chamber “Memmert HPP260eco” (Germany, 2019) at 25±2.0 °C, relative humidity of 60 ± 10 % and the

**Table 1.** Comparative morphology of the imago of *U. senex* Grese

Imago	Characteristics
Number of linear sensilla (female)	4 in the first segment of the club
Antennae (male)	A club with a less prominent third segment. The ratio between the length of club segments 1 and 2 : 1.3–1.5 (a longer segment 1)
Radial vein of the wing	The ratio between the length of the radial vein and the wing width: 0.21–0.24
Genitalia (male)	The genitalia are elongated, with the characteristic back curvature, which is a distinctive feature as compared to related species, for instance, <i>U. caryedoni</i>
Forewings (male and female)	Pubescent, but less conspicuous than in <i>U. espiniae</i> . <i>Fringe setae</i> are shorter: < 0.13 of the wing width
Coloring	Yellowish-brown, typical of representatives of the genus <i>Uscana</i> spp., antennae and legs are distinctly darker.

photoperiod of 16 : 8 (L : D). The eggs of broadbean seed beetle were used as an alternative host insect (*Acanthoscelides obtectus* Say.). The phytophage was given common beans (*Phaseolus vulgaris* L.) as the main component of the nutrient substrate, which was placed in glass bulbs of 0.5 and 1 l. The bulbs were kept under stable hydrothermal modes, which ensured obtaining biomaterial for further stages of the study. At the same time, more than 1 million entomophagous individuals were reared in laboratory conditions to implement the tasks set.

To determine the effect of the parasite:host ratio on reproductive indices, newly hatched females of *U. senex* of the same age were used, which had not been in contact with the host insect prior to the experiment. In each experimental variant, conditions with different parasite:host ratios (from 1 : 1 to 1 : 45) were created, with each variant having 8 repeats ( $n = 8$ ). Potential fecundity was determined as the ratio of the number of females to the total number of parasitized eggs in the sample. Actual fecundity was assessed by counting the number of imagoes that hatched from infected eggs. Host utilization efficiency was determined as the proportion of black parasitized eggs in the total mass. The gender ratio of the offspring was determined as the number of males per one female.

The study also included an examination of the biological indices of the parasite between different lines of its populations, in particular, native, laboratory, and adapted ones. At the same time, the native (natural) population of *U. senex*, i.e. one that developed in natural conditions without artificial intervention, was formed by collecting parasitized eggs directly from populations of the pea weevil (*B. pisorum* L.). The laboratory population consisted of a group of individuals reared under controlled conditions, isolated from the natural environment, and cultivated on the eggs of *A. obtectus* Say. In addition, it was kept for three consecutive generations without any contact with the natural host (*B. pisorum* L.). The adapted population was defined as a group of individuals that had acquired stable biological and behavioral characteristics as a result of repeated passaging of several generations of the entomophage through the natural host, *B. pisorum* L. and was released into pea agrocenoses to control the population of the pea weevil.

To assess the effectiveness and viability of the parasite *U. senex* in each of the studied lines, such

biological indices as fecundity, motor activity, migration and searching ability, imago restoration, and the proportion of deformed individuals were evaluated.

The fecundity of *U. senex* females (eggs/female) was determined by counting the number of eggs parasitized by a female during its life cycle. For each population, 20–30 females were selected and kept separately in test tubes. Every day, the females were exposed to 300–400 fresh eggs of the host.

Motor activity (cm/min) was measured using video recording, in particular, the movement of individual specimens on a horizontal surface (10 × 10 cm arena) was recorded for 1 min. Migration and searching ability (%) was determined by counting the share of individuals capable of finding the host eggs in the biotest conditions. For this purpose, a 3 m long maze was used, in which the host eggs were placed. The imago and host eggs were exposed for 8 hours.

The restoration of *U. senex* imago (%) was determined as the proportion of individuals that hatched from the total number of infected eggs. The index was assessed after 10–14 days. The number of deformed individuals (%) was determined by registering individuals with abnormalities (deformities of the wings, legs, and abdomen) that hatched from the eggs of the broadbean seed beetle.

**1.3. Field studies.** The field experiment was conducted in an agrocenosis on the fields of common pea (*P. sativum*) of the Oplot cultivar, where an increased level of pea weevil (*Bruchus pisorum* (Linnaeus, 1758) was observed. The parasite was released on three pea fields with an area of 1 hectare, located 50 m apart. In each variant, different parasite:host ratios were used (from 1 : 5 to 1 : 40). The control (without releasing the parasite) involved assessing the natural background, with the plot located 150 m away from the experimental plots. *U. senex* was released during the mass egg-laying phase of the pea weevil. The experimental plots were separated by protective strips 25 m wide (Parra, 2014; Bradowsky et al., 2017; Reddy et al., 2018).

The following indices were evaluated: egg parasitism (% of the total number of host eggs on the recorded plants), pea seed damage (% of the total number of seeds damaged by the host). The survey was conducted once every 5 days, with samples taken (20 plants per one repeat) at distances of 2.5, 5.0 and 7.5 m from the entomophage release site, which determines the percentage of phytophagous egg para-

sitism. A control plot where no entomophages were released was used as a control. This allowed us to compare the effectiveness of parasitism of *B. pisorum* L. eggs in the presence and absence of entomophages (Gonthier et al., 2023).

Statistical analysis of the results was performed using ANOVA, and the data in the tables were presented in the form of  $x \pm SD$  (mean  $\pm$  standard deviation). The difference between groups was considered significant using the Tukey test, at  $P < 0.005$ .

**RESULTS**

Table 2 shows the results of studies on the effect of different parasite:host ratios on the bioecological indices of the parasite *U. senex*. The data obtained indicate that with an increase in the number of host insects, there was a gradual increase in both the potential and actual fecundity of the parasite. In particular, potential fecundity increased from 9.12 eggs/female at a ratio of 1:1 to 32.03 eggs/female at a ratio of 1:45. A similar trend was observed for actual fecundity as well, which reached its highest values (25.48 eggs/female).

At the same time, the host utilization efficiency, which was over 94% at the beginning of the experiment, gradually decreased to below 69%, indicating a certain saturation limit of the parasite with available resources. The decrease in this index may be due to either limitations in the biological potential

of the parasite or behavioral factors that reduce the effectiveness of parasitism when the host population is high.

An interesting distribution of genders in the offspring was noted: at the initial stages, the ratio of males to females exceeded one, indicating a predominance of males, but as the host population grew, this ratio decreased to 0.62–0.69, i.e., with the increasing availability of the host, a feminised composition of the offspring was formed. This pattern corresponds to well-known trends for egg parasitoids, where the gender ratio often depends on population size and rearing conditions.

Table 3 shows a comparison of the biological indices of the parasite *U. senex* obtained from different breeding lines, in particular the laboratory population, three generations after passaging through the natural host *B. pisorum*, and the native population. The study covered five key parameters of viability: female fecundity, motor activity, migration and searching ability, percentage of imago restoration, and proportion of deformed individuals.

The results obtained (see Table 3) show that the laboratory population had the lowest values for most indices: its representatives were characterized by reduced fecundity — 21.26 eggs/female, the lowest motor activity — 8.28 cm/min, as well as the lowest searching ability — 55.82% and restoration rate —

**Table 2.** The impact of the parasite:host ratio on the bioecological indices of the parasite *U. senex* Grese, ( $x \pm SD$ , n=8)

The ratio, parasite:host	Reproductive indices of the imago of the parasite <i>U. senex</i> Grese			
	Potential fecundity, eggs/female	Actual fecundity, eggs/female	Efficiency of host utilization, %	The ratio between genders, males/female
1:1	9.12±1.24 <sup>a</sup>	5.72±0.07 <sup>a</sup>	94.46±4.25 <sup>a</sup>	1.37±0.06 <sup>a</sup>
1:3	9.96±2.38 <sup>a</sup>	6.84±0.09 <sup>a</sup>	94.19±2.15 <sup>a</sup>	1.29±0.04 <sup>a</sup>
1:5	11.42±1.46 <sup>ab</sup>	7.05±0.12 <sup>b</sup>	93.06±3.36 <sup>a</sup>	1.13±0.11 <sup>a</sup>
1:7	14.49±2.62 <sup>bc</sup>	7.48±0.23 <sup>b</sup>	93.41±2.17 <sup>a</sup>	1.46±0.05 <sup>a</sup>
1:10	15.83±2.51 <sup>c</sup>	8.73±1.27 <sup>bc</sup>	89.27±3.69 <sup>b</sup>	0.92±0.17 <sup>ab</sup>
1:15	18.66±2.22 <sup>d</sup>	9.11±2.38 <sup>c</sup>	85.64±1.92 <sup>c</sup>	0.84±0.03 <sup>b</sup>
1:20	19.73±3.73 <sup>de</sup>	10.07±2.16 <sup>c</sup>	84.69±4.28 <sup>c</sup>	0.89±0.09 <sup>b</sup>
1:25	20.64±2.66 <sup>de</sup>	12.62±2.26 <sup>d</sup>	77.54±2.42 <sup>d</sup>	0.71±0.25 <sup>b</sup>
1:30	30.85±3.57 <sup>e</sup>	18.73±1.62 <sup>e</sup>	76.62±3.18 <sup>d</sup>	0.74±0.07 <sup>b</sup>
1:35	31.42±2.42 <sup>e</sup>	19.47±3.37 <sup>e</sup>	70.88±4.03 <sup>e</sup>	0.65±0.36 <sup>c</sup>
1:40	31.91±2.54 <sup>e</sup>	24.94±3.49 <sup>f</sup>	69.05±2.59 <sup>ef</sup>	0.62±0.23 <sup>c</sup>
1:45	32.03±3.67 <sup>e</sup>	25.48±0.56 <sup>f</sup>	68.32±3.28 <sup>f</sup>	0.69±0.12 <sup>c</sup>

Note: Different letters denote values that differed significantly from each other within the same column of the table (Tukey’s criterion,  $P < 0.05$ ).

**Table 3.** The biological indices of the parasite *U. senex* Grese of different rearing lines ( $x \pm SD$ ,  $n=5$ )

Line of rearing a parasite population		Viability indices of the parasite <i>U. senex</i> Grese				
		Fecundity, eggs/female	Motor activity, cm/min	Migration and searching ability, %	Restoration of the parasite imago, %	Number of deformed insects, %
Laboratory		21.26±2.92 <sup>a</sup>	8.28±1.76 <sup>a</sup>	55.82±2.87 <sup>a</sup>	70.82±4.01 <sup>a</sup>	5.63±0.37 <sup>c</sup>
Adapted after passaging	F1*	31.09±2.53 <sup>c</sup>	12.81±3.74 <sup>b</sup>	69.74±1.53 <sup>b</sup>	89.01±2.74 <sup>b</sup>	2.02±0.09 <sup>b</sup>
	F2	30.06±3.34 <sup>bc</sup>	12.42±3.37 <sup>b</sup>	68.37±3.68 <sup>b</sup>	86.19±2.65 <sup>b</sup>	2.89±0.17 <sup>b</sup>
	F3	29.83±2.57 <sup>b</sup>	10.64±4.42 <sup>ab</sup>	68.02±1.74 <sup>b</sup>	85.47±2.29 <sup>b</sup>	3.47±0.05 <sup>bc</sup>
Native		33.27±2.14 <sup>c</sup>	11.53±3.04 <sup>ab</sup>	85.12±4.03 <sup>c</sup>	93.31±3.27 <sup>c</sup>	0.93±0.02 <sup>a</sup>

Note: Different letters denote values that differed significantly from each other within the same column of the table (Tukey's criterion,  $P < 0.05$ ).

\* F1–F3 — generations of the parasite after passaging through the natural host *B. pisorum*.

70.82%. At the same time, this variant had the highest percentage of deformed individuals, 5.63%, which in turn indicated a potential deterioration in the quality of offspring under conditions of prolonged laboratory rearing.

After passaging through the natural host, a significant improvement in most biological parameters was noted already in the first generation. In particular, in the adapted population, fecundity increased to 31.09 eggs/female, and motor activity — to 12.81 cm/min, which was statistically significantly higher than the laboratory population. The indices of the second and third generations remained consistently high, although slightly lower than those of the first generation, which indicated the preservation of the positive effect of passaging over several generations.

The highest fecundity values of 33.27 eggs/female, searching ability — 85.12%, and imago restoration — 93.31% were observed in the native population. This line was also characterized by the lowest number of deformed individuals (0.93%), indicating high adaptation and stable biological potential in natural conditions.

Overall, the results demonstrated that the passaging of the laboratory population of *U. senex* through a natural host contributed to the restoration of its viability and high adaptability, bringing key biological characteristics closer to the level of the native population. This is of practical importance for maintaining the effectiveness of the parasite during mass laboratory rearing for biological control in agroecosystems.

Under field conditions (Table 4), the highest level of parasitism of pea weevil eggs was recorded in the

1:5 ratio variant, where the share reached 39.8%, which significantly exceeded all other variants. Slightly lower, but also high parasitism rates were observed in variants with a ratio of 1:10 — 26.21% and 1:15 — 24.43%. With a further increase in the number of hosts, the level of parasitism of *U. senex* Grese gradually decreased: in the 1:20–1:40 variants, it varied from 23.8 to 15.21%, respectively. In the control variant, where the entomophage was not released, the rate of natural parasitism was only 8.36%, which was the lowest value among all variants.

**Table 4.** Biological efficiency of the release of *U. senex* in the field conditions on the plots of Oplot cultivar against *B. pisorum* under different parasite:host ratios ( $x \pm SD$ ,  $n = 4$ )

Ratio variants, parasite:host	Evaluated parameters, %	
	Parasitized eggs <i>B. pisorum</i> L.	Damaged pea seeds
Control (natural background)	8.36±1.46 <sup>a</sup>	14.39±3.67 <sup>d</sup>
1:5	39.80±4.12 <sup>c</sup>	5.59±2.61 <sup>a</sup>
1:10	26.21±2.48 <sup>d</sup>	8.78±4.77 <sup>b</sup>
1:15	24.43±3.51 <sup>cd</sup>	9.67±3.09 <sup>b</sup>
1:20	23.80±2.95 <sup>c</sup>	9.87±1.67 <sup>b</sup>
1:25	22.23±3.16 <sup>c</sup>	10.63±2.97 <sup>bc</sup>
1:30	20.31±2.43 <sup>bc</sup>	11.78±2.23 <sup>c</sup>
1:35	18.11 ±1.87 <sup>b</sup>	12.56±2.28 <sup>c</sup>
1:40	15.21 ±2.03 <sup>b</sup>	13.24±3.07 <sup>cd</sup>

Note: Different letters denote values that differed significantly from each other within the same column of the table (Tukey's criterion,  $P < 0.05$ ).

Regarding damage to pea seeds (see *Table 4*), the lowest percentage was found in the 1:5 variant — 5.59%, which indicated high effectiveness of biological control under conditions of maximum parasite-to-host ratio. The seed damage values gradually increased with a decrease in the number of entomophages: in variants with a ratio of 1 : 10–1 : 25, it ranged from 8.78 to 10.63%. The highest damage rate was recorded in the control variant (14.39%), which significantly exceeded the corresponding indices in all variants with the release of entomophages.

Thus, the highest biological efficiency in field conditions was shown by the variant with a ratio of 1 : 5, which proved to be optimal both in terms of egg parasitism and minimal damage to pea seeds.

## DISCUSSION

In this study, we analyzed literature sources on the laboratory rearing of entomoparasites of pea weevil eggs and other seed beetle species and concluded that *U. senex* Grese cannot be reared in laboratory conditions on its natural host (*B. pisorum* L.). We proposed another host for the entomophage rearing — the broadbean seed beetle (*A. obtectus* Say), which proved to be suitable for laboratory conditions.

Phytophagous insects are one of the main obstacles to pea cultivation (Nikolova, 2024). Among them, noteworthy is the pea weevil (*B. pisorum* L.), as it is an economically significant pest worldwide. Its larvae develop inside the seed, causing serious losses in weight, deterioration in quality, and reduced viability of the seed (Ternovyi et al., 2021). In some regions, these losses are critical: in Ethiopia, seed weight loss reached 85% and germination rate loss reached 59% (Mendesil et al., 2016); in India, seed contamination during storage reached 70–90% (Kalpna et al., 2022); in the United States, damage covered 42–82% with a weight loss of up to 25% (Mendesil et al., 2022). A similar situation was observed in Australia, where infection rates reached 15–20% (CABI, 2022).

Despite active research, a high level of protection of pea plants against the pea weevil has not yet been achieved, and the proposed solutions, such as breeding, have limited effectiveness. For example, in a study (Nikolova, 2016), five pea cultivars were investigated, among which the Glyans and Modus cultivars showed better resistance. However, even in the least affected samples, it was not possible to completely avoid pest egg laying or seed damage. This indicates

partial but not complete resistance, which reduces their effectiveness in field conditions.

Recent GWAS studies on 324 genotypes also found significant natural variation in infection levels, but even the most resistant varieties showed about 10% infestation, which is not sufficient for complete protection under high pest pressure (Osuna-Caballero et al., 2024). Thus, despite the availability of partially tolerant cultivars, there are currently no pea cultivars, completely resistant to *B. pisorum* L., which creates a need for an integrated approach combining breeding and biological control.

There are many natural enemies of the pea weevil (*B. pisorum*), among which egg-eating and larval parasitoids from the Trichogrammatidae and Pteromalidae families play a leading role (Bellifa et al., 2021; Gailis et al., 2021). These entomophages are capable of significantly reducing the number of pests both in the field and in grain storage facilities (Lisovyi, 2004). Of particular interest are species of the genus *Uscana* spp., which parasitize the eggs of the pea weevil (*B. pisorum* L.), preventing the development of the pest in its early stages (Polaszek et al., 2023).

Field studies have shown high effectiveness of *U. senex* Grese in the biological control of the pea weevil (*B. pisorum*). The parasitism rate varied from 40% to 80% (Aryamanesh et al., 2012; Sharma et al., 2018). This difference was observed depending on the density of the entomophagous release (Konverska et al., 2014). In particular, it was noted that the highest parasitism rate was recorded under conditions of two releases of 15.2 million individuals/ha during the period from the beginning of blossoming to full ripening of the pods (Reddy et al., 2018). However, there are other reasons for the low effectiveness of entomophages that are not only related to the timing and rates of release into the agrocenosis (Effowe et al., 2010).

The successful integration of *U. senex* into the pea protection system requires not only strict adherence to agrotechnical parameters, but also careful quality control of the biomaterial used for introduction (Lysenko & Chernova 2017). Our research covered several aspects that determine the effectiveness of laboratory populations of the endoparasite *U. senex* (Sood et al., 2003), in particular: the effect of the parasite:host ratio on the reproductive and bioecological parameters of the entomophage, the viability of different breeding lines (industrial, laboratory after

passaging, and native), as well as the level of biological effectiveness when releasing the parasite in field conditions. The results obtained indicated significant variability in biological characteristics depending on breeding conditions and the ratio with the host, and also emphasized the importance of passaging through the natural host *B. pisorum* L. to maintain the viability of the parasite (Spitzen et al., 2005).

Studies have shown that one of the important factors is the parasite:host ratio, which ensures effective infection of the eggs of the pest *B. pisorum* L., which in turn guarantees stable growth of the population of the entomophage *U. senex* Grese during the growing season of peas (Fatouros et al., 2020). In addition, an increase in the density of the parasite in the system of increasing the parasite:host ratio contributes to an increase in the fecundity of females and an increase in the realization of potential fecundity.

In addition, Wang et al. (2020) note that the viability of the parasite is also a key factor. In particular, adapted individuals of *U. senex* demonstrated a higher ability to find a host, a longer period of activity, and higher fecundity, which are critical factors for achieving maximum effectiveness in controlling the phytophage *B. pisorum*. On the other hand, the release of weakened individuals or egg parasitoids with reduced viability can significantly reduce the level of parasitism, even when optimal release times and rates are observed.

In laboratory conditions for mass rearing of *U. senex*, it is reasonable to use an alternative host — the broadbean seed beetle (*A. obtectus*), which is much more amenable to domestication than the natural host — the pea weevil (*B. pisorum*) (Stolk et al., 2005). Due to its high rearing stability and lower demands, the broadbean seed beetle provides an effective platform for mass rearing of entomophagous populations (Pintureau et al., 1999). However, to preserve adaptive characteristics and increase field efficiency, we recommend passing the parasite through a natural host (Sankara et al., 2014). This approach helps restore specific behavioral and physiological traits necessary for effective search and parasitism of *B. pisorum* in the agroecosystem. Thus, the successful integration of *U. senex* Grese into the pea crop protection system requires not only strict adherence to agrotechnical parameters but also careful control of the quality of biomaterial, including laboratory rearing conditions, host selection, and strategic passaging through the natural host.

The research results are of theoretical and practical importance for biological control practices, as they allow for the improvement of approaches to mass laboratory rearing and release of the entomophagous *U. senex* Grese into pea agroecosystems, taking into account its adaptive potential. The proposed solutions will contribute to reducing the use of insecticides, preserving the biodiversity of agroecosystems, and developing environmentally safe technologies for growing grain legumes. The introduction of *U. senex* Grese entomoculture as part of integrated protection systems not only increases the biological effectiveness of regulating the population of the pest *B. pisorum* L., but also contributes to the transformation of agricultural production into a more environmentally responsible and resource-saving model.

## CONCLUSION

The results of the study of the bioecological indices of the entomophage *U. senex* Grese on the eggs of the alternative host *A. obtectus* Say for rearing in laboratory conditions and the effectiveness of using the entomophage against *B. pisorum* L. in natural conditions on the Oplot pea cultivar are presented. Based on the results of the study, the following main conclusions can be drawn.

1. It has been found that *U. senex* Grese differs morphologically from species of the genus *U. spp.*, in particular, by a greater number of sensilla on the first segment of the club (4 vs. 3), an elongated first segment of the club, a shorter radial vein, and more massive genitalia.

2. It has been established that different parasite:host ratios affect the bioecological indices of the parasite *U. senex* Grese: with an increase in the number of host insects, a gradual increase in both the potential and actual fecundity of the parasite has been observed, in particular, potential fecundity increased from  $9.12 \pm 1.24$  eggs/female at a ratio of 1:1 to  $32.03 \pm 3.67$  eggs/female at a ratio of 1:45, and actual maximum fecundity was  $25.48 \pm 0.56$  eggs/female.

3. The biological parameters of the parasite *U. senex* Grese obtained from different breeding lines, in particular the laboratory population, three generations after passaging through the natural host *B. pisorum* and the native population, were analyzed and compared. The laboratory population had the lowest values for most indices: its individuals were characterized by reduced fecundity —  $21.26 \pm 2.92$  eggs/fe-

male, the lowest motor activity —  $8.28 \pm 1.76$  cm/min, as well as the lowest searching ability —  $55.82 \pm 2.87\%$  and the lowest restoration rate —  $70.82 \pm 4.01\%$ . At the same time, this variant had the highest percentage of deformed individuals,  $5.63 \pm 0.37\%$ , which in turn indicated a potential deterioration in the quality of offspring under conditions of long-term laboratory rearing.

4. It has been found that the passaging of the laboratory population of *U. senex* Grese through its natural host *B. pisorum* L. contributed to the restoration of its viability and high adaptability, bringing its key biological characteristics closer to those of the native population. This is of practical importance for maintaining the effectiveness of the parasite during mass laboratory rearing for biological control in agrocenoses.

5. The biological effectiveness of using *U. senex* Grese in field conditions on crops of the Oplot pea cultivar against *B. pisorum* L. at different parasite: host ratios, and the highest level of parasitism of pea weevil eggs was observed in the variant with a ratio of 1 : 5, where the share reached  $39.8 \pm 4.12\%$ .

6. It was found that the lowest percentage of damage to Oplot peas was observed in the 1 : 5 ratio ( $5.59 \pm 2.61\%$ ), which indicated high effectiveness of biological control under conditions of maximum parasite: host ratio.

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**ОСОБЛИВОСТІ РОЗМНОЖЕННЯ  
ЛАБОРАТОРНОЇ ПОПУЛЯЦІЇ *USCANA  
SENEX* (GRESE, 1923) ТА ЇЇ АДАПТИВНИЙ  
ПОТЕНЦІАЛ В АГРОЦЕНОЗАХ ГОРОХУ  
ПОСІВНОГО ПРОТИ *BRUCHUS PISORUM*  
(LINNAEUS, 1758)**

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**Мета досліджень** — оцінити біоекологічні особливості та репродуктивний потенціал яйцепаразита *Uscana senex* (Grese, 1923) (Hymenoptera: Trichogrammatidae) з метою використання його в програмах біологічного контролю зерноїда горохового (*Bruchus pisorum* (Linnaeus, 1758) (Coleoptera: Chrysomelidae)). **Методи.** Видову приналежність паразита встановлювали за морфологічними ознаками, а також шляхом детального аналізу будови геніталій та форми булав імаго. Комплекс лабораторних досліджень для визначення біоекологічних показників *U. senex* Grese проводився впродовж 2022 — 2024 рр. Технологічні прийоми розведення паразита здійснювали за відомими методиками у нашій модифікації (Wang et al., 2014; Bradowsky V. & Bradowsky N., 2022; Statkevych et al., 2024). Маточну культуру формували шляхом вилову комах із природних екосистем. Ентомофага підтримували за допомогою кліматичної камери “Memmert HPP260eco” (Німеччина, 2019) за температури  $25 \pm 2,0$  °C, відносної вологості  $60 \pm 10$  % і фотоперіоду 16:8 (L:D). У якості альтернативної комахи-господаря використовували яйця зерноїда квасолевого (*Acanthoscelides obtectus* Say.). Фітофагу пропонували квасоллю звичайну (*Phaseolus vulgaris* L.) як основний компонент поживного субстрату. Для виконання поставлених завдань у лабораторних умовах було вирощено понад 1 млн особин ентомофага. У лабораторних і польових умовах за загальноприйнятими ентомологічними методами досліджували вплив різного співвідношення паразит:господар (від 1:1 до 1:45) на репродуктивні характеристики ентомофага.

Порівнювали основні показники життєздатності лабораторної та природної популяції паразита: рухову активність, пошукову здатність, рівень відродження та частку деформованих особин. Також оцінювали вплив періодичного пасажу лабораторної культури через природного господаря на якість біоматеріалу. Статистичну обробку результатів здійснювали методом дисперсійного аналізу (ANOVA), дані наведено у формі  $x \pm SD$ . **Результати.** Дослідження показали, що зі зростанням кількості поколінь ефективність використання паразита знижується. Найвища біологічна ефективність у польових умовах на посівах гороху сорту “Оплот” була зафіксована при співвідношенні 1:5, де рівень паразитування становив 39,8%, а пошкодження зерна було мінімальним — 5,59%. Було виявлено статистично значущі відмінності між нативною та лабораторною популяціями *U. senex*, де нативна популяція демонструвала вищі показники життєздатності порівняно з лабораторною. Періодичний пасаж лабораторної популяції через природного господаря частково компенсував втрати життєздатності та знижений репродуктивний потенціал. **Висновки.** Отримані результати засвідчили високу ефективність *Uscana senex* як біологічного агента в інтегрованих системах захисту гороху від *Bruchus pisorum*. Доведено, що підтримання репродуктивного потенціалу та життєздатності паразита забезпечується за умови періодичного контакту лабораторної популяції з природним господарем і дотримання оптимального співвідношення паразит:господар, що сприяє збереженню стабільної якості біоматеріалу.

**Ключові слова:** ентомофаг, фітофаг, лабораторна культура ентомофага, біологічний контроль, життєздатність, ефективність, зернобобові культури.