RHAGOLETIS BATAVA HERING (DIPTERA, TEPHRITIDAE) PROBLEM IN SEA BUCKTHORN PLANTATIONS IN LITHUANIA

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Abstract

Data from the Association of Sea buckthorn Growers in Lithuania shows that approximately 2,500 hectares in the country are currently covered with sea buckthorn. It was previously a common belief that sea buckthorn was the only plant suitable for organic farming, as it was thought to be free from pest attacks. However, this is no longer the case. The sea buckthorn fly (Rhagoletis batava, Hering) has now become widespread in sea buckthorn plantations. Since 2015, studies on the abundance, biology, harmfulness, and control methods of the sea buckthorn fly were conducted in plantations located in the southern and northern Lithuania. The results showed that the activity of the sea buckthorn fly in the southern plantation began during last decade of July, peaked on beginning of August, and the last pests were detected during the end of August and beginning of September. The plant protection product of the biological origin used for sea buckthorn fly pupae control was ineffective.

Keywords: *plant protection, sea buckthorn fly, pest control, integrated pest management*

INTRODUCTION

Sea buckthorn (*Hippophae* L.) is a representative of the genus *Hippophae*, belonging to the family Elaeagnaceae, the class Magnoliopsida, and the division Magnoliophyta [1]. The plant grows as a shrub or small tree reaching about 6 meters in height, with a distribution range in Asia and Europe [2].

Sea buckthorn is characterized by a high abundance of vitamins and biologically active substances, more so than in many garden plants [2]. Sea buckthorn fruit contains a lot of vitamin C (ascorbic acid), bioflavonoids, beta carotene, B-group vitamins (thiamine (B1), riboflavin (B2), choline (B4), vitamin B6, inositol (B8), folic acid (B9)), other groups of vitamins (tocopherol (E), F, K1, niacin (PP), calciferol (D)), serotonin, betaine, coumarin, triterpene acid, succinic acid, pectin, and fats [3]. In terms of percentage composition, it should be emphasized that sea buckthorn fruits contain on average 79% water, 3% carbohydrates, 3% acids, 4% fats, and about 11% various vitamins, minerals, and other components [4]. It is stated that sea buckthorn berries have very little sugar (only 3–6%) and quite a lot of acids (1–3%), depending on the variety or the granulometric composition of the soil. Fats are found in all parts of sea buckthorn, but in different quantities: 2–10 % in the pulp and skin of the fruit, 5–17 % in the seeds, 3 % in the bark, 0.1–0.9 % in the leaves [5]. Sea buckthorn fruits contain microelements such as Fe, Mn, Mg, B, S, Al, Sn, Cl, Ni, Pb, Mo, Cu, and others [6]. The pharmacological properties of sea buckthorn oil are particularly valued in medicine. Sea buckthorn oil is used as an anti-inflammatory, antibacterial, disinfectant, pain reliever, and tissue regeneration promoter. It can also be used in cosmetology and for treating corneal wounds [7].

In 2023, there were 15,682.99 hectares of cultivated horticulture plants declared in Lithuania, of which 14.94% (2,343.47 hectares) were sea buckthorn orchards. In recent years, the area of sea buckthorn plantations in Lithuania has significantly expanded. The average area of declared sea buckthorn orchards has become the largest among berry orchards. Several reasons have driven the expansion of sea buckthorn cultivation: the exploration for new business opportunities, the recognition of their fruits as a health-promoting food product, and the possibility of receiving state financial support for orchards and berry plantations [8]. For a long time, it was stated that sea buckthorn is one of the most suitable plants for organic farming in Lithuanian climatic conditions, as it has almost no serious pests or diseases. However, over the past decade, the situation has changed significantly, and sea buckthorn seedlings can be severely affected by various diseases and pest damage. Regarding sea buckthorn diseases, in Lithuania, these plants are most commonly affected by wilts caused by fungi of the genera *Verticillium* spp. and *Fusarium* spp. Meanwhile, the range of pests in sea buckthorn plantations is significantly more diverse. Larvae of the gypsy moth (*Lymantria dispar*) gnaw on leaves and young terminal shoots. Caterpillars of moths (Torticidae) and especially of the sea buckthorn moth (*Gelechia hippophaella*) also severely damage the leaves of the plants. Various species of cicadas (Aphrophoridae), aphids (*Capitophorus hippophaes, C. elaeagni, C. similis*) suck the sap from the leaves and non-woody shoots of the plants. Gall mites (*Aceria hippophaena*) not only feed on the plant sap but also form small galls on the leaves. However, the most harmful sea buckthorn pest in Lithuania is the sea buckthorn fly (*Rhagoletis batava*) [8]. *Rh. batava* was first detected in Lithuania in 2012 [9]. Although the sea buckthorn fly is considered native to Siberia, it has spread to many European countries over the past 15 years [10]. The pest specializes exclusively on sea buckthorn berries [11; 12]. *Rh. batava* is a thermophilic insect. The timing of the beginning of adult flight depends on the temperature conditions of the preceding weeks [12]. The activity of adult flies in Russia begins to be recorded from mid-June at an average temperature of 18°C [3]. It takes up to 6 weeks for an adult to emerge from the puparium. Since pupae of sea buckthorn fly overwinter in the soil, the emergence of adults from the pupae is highly dependent on soil temperature [13]. This process is most active for about a week and usually occurs in the first half of July. Flying, mating, and egg laying only occur in warm, sunny weather. Six to fourteen days after the start of flying, females begin laying eggs, placing them one by one under the skin of the fruit. Sometimes, 2-4 eggs can be laid in one berry [14]. The fertility of a single female reaches 200 eggs or more. Adults feed on the ovipositional site by piercing the fruit skin and licking its juices [12; 15]. Prolonged cool and rainy weather in summer reduces fly activity [4; 13]. The adult flying period lasts about two months. The sum of average active air temperatures reaches 377°C [16]. Sudden temperature drops to 10–11°C during the adult flight period reduce the abundance of pests. For three to four weeks, the larvae feed on the pulp of the fruit, leaving the thin fruit skin untouched [12]. The larvae grow up to 6–7 mm, and if there is not enough food in one fruit, they move to the neighbouring fruit [17]. At the initial stage of infestation, an orange spot appears on the green fruit, and later the entire fruit turns orange. Mature larvae fall to the ground, burrow to a depth of 1–5 cm, form the puparium, and overwinter [3].

Under favourable conditions, this pest can destroy the entire crop [3; 10; 8]. Therefore, the selection and application of control methods are very important to preserve the yield. The sea buckthorn fly has a natural enemy, the parasitic wasp *Opius rhagoleticollis*. In some years, this wasp can destroy up to 70% of the fly pupae [13]. Mulching can be applied for the control of the sea buckthorn fly [18; 13]. This problem can be successfully addressed by growing pest-resistant or relatively resistant varieties [12; 19; 8]. If sea buckthorn is grown non-organically, the spread of the sea buckthorn fly can be controlled with insecticides. The application of the insecticide Phytoverm for plant protection has allowed the crop to be grown without toxic residues [12]. In Germany, Mospilan is permitted for use against the sea buckthorn fly [14]. Biological and chemical insecticides should be used for the first time a few days after the start of adult flying. It is recommended to repeat the spraying 7–10 days later [8]. Yellow sticky traps have proven to be the most suitable for monitoring the spread of the sea buckthorn fly. Blue, red, and black traps were not as attractive [20].

Male of sea buckthorn fly secrete the pheromone (-)-δ-heptalactone. It has been found that the pheromone (-)-δ-heptalactone is attractive to adult flies of both sexes. In pheromone traps, this olfactory stimulant attractant shows promise for the monitoring and control of the sea buckthorn fly [21]. Currently, much attention is being given to the search for alternatives to traditional pesticides. One of the important developments in this direction is the evaluation of pheromones as biologically active compounds that alter insect behaviour in pest management. Pheromones, as low-biological-activity substances, protect plants from insect damage and reduce the need for insecticides in crops, thereby also reducing the risk of environmental and food contamination [22; 23].

The aim of the study was to investigate the abundance, biology, harmfulness, and control methods of the sea buckthorn fly in plantations located in southern and northern Lithuania.

MATERIALS AND METHODS

Research was conducted in private sea buckthorn plantations in southern and northern Lithuania. Observations have been continuously conducted since 2015.

Sticky traps were used to determine the beginning and abundance of the sea buckthorn fly flight. There were two types of traps: white Delta type and yellow. Eight traps of each colour were hung in the orchards, one on every fifth tree, during the first decade of June. The traps were checked and replaced weekly.

Since sea buckthorn flies overwinter as pupae [3; 12; 24] in the soil surface under sea buckthorn trees, well-sealed insectary cages [14] were set up under the trees to determine the exact time, abundance, and speed of adult emergence from pupae, and to evaluate the effectiveness of a biological plant protection product for pest control. These insectary cages were 80 cm in diameter and 1 m high, consisting of a metal frame covered with entomological netting. One yellow trap was hung in the centre of each cage. In the isolated environment, adult flies caught in the traps were counted, and the traps were replaced weekly.

A biological plant protection product was used to control the overwintering pupae of the sea buckthorn fly. The active ingredient of this product was the invasive juveniles (J2) of the entomopathogenic nematode (EPN) *Steinernema carpocapsae*. The experiment was conducted with three variants, arranged randomly in four replications:

1) control variant (water used);

2) 0.5 million *Steinernema carpocapsae* J2 per square meter;

3) 1.0 million *Steinernema carpocapsae* J2 per square meter.

The suspension of the biological plant protection product was prepared just before use according to the manufacturer's recommendations. The product was applied twice. The first application of the prepared product suspension was done during the first decade of June, before the appearance of the first adult sea buckthorn flies. The application was repeated after two weeks.

To determine the most attractive dose of the pheromone (-)-δ-heptalactone for the sea buckthorn fly, yellow MacPhail traps filled with different amounts of pheromone were used. A trial with three replications and six variants was conducted:

1) Control variant (no pheromone used);

2) 6 μL of pheromone used;

3) 15 μL of pheromone used;

4) 25 μL of pheromone used;

5) 50 μL of pheromone used;

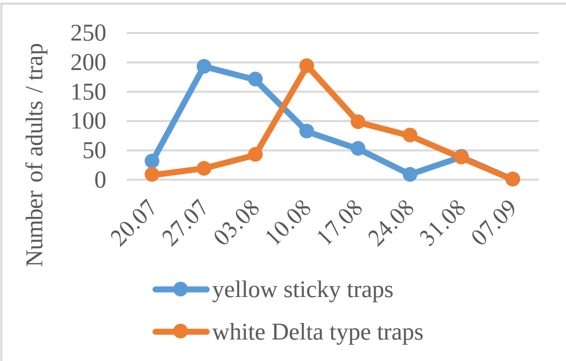
6) 75 μL of pheromone used.

To evaluate the attractiveness of the pheromone, pads saturated with different amounts of the pheromone (-)-δ-heptalactone were placed in special holders in McPhail type traps. Water was added to the bottom of the traps, which were then sealed. The McPhail traps were hung on selected trees at a height of 1–1.5 meters.

Three replicates of the experiment were set up in different rows of sea buckthorn trees, maintaining a 10-meter distance between the three replicates and applying a 10-meter distance between the test variants. The traps were hung during the peak flight period of the adult flies at the end of July. The contents of the traps were checked and counted weekly.

RESULTS AND DISCUSSION

Yellow and white Delta-type sticky traps were hung in sea buckthorn orchards during the first decade of June to determine the beginning of the adult sea buckthorn fly flight and to monitor changes in pest abundance dynamics. The first adult of sea buckthorn fly was detected in the traps only in mid-July 2015 (Fig. 1). On average, 31.5 specimens were caught per yellow trap, while the white traps were significantly less attractive, capturing only 8 specimens per trap. In the following season, adult flies appeared even later, only at the end of July. However, the pests were significantly more active, with an average of 68.3 specimens caught per yellow trap and 44.5 specimens per white trap. Meanwhile, Shamanskaya [12] observed the first adult of sea buckthorn fly already in June. In the Mecklenburg-Vorpommern region of Germany, the first adult flies were caught on June 16th [14]. It is likely that the later appearance of adult sea buckthorn flies in Lithuanian sea buckthorn plantations was influenced by prevailing rainy weather, as cool and rainy conditions negatively affect their viability and activity [4; 13].



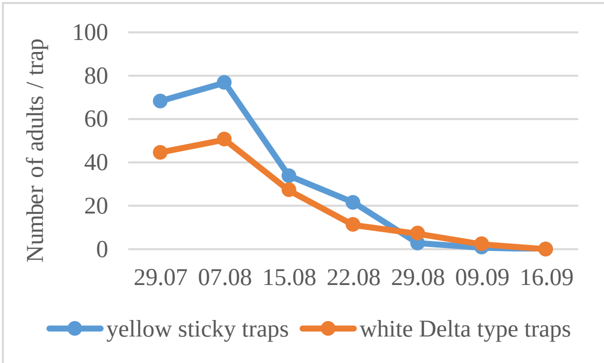


Fig. 1. The number and abundance dynamics of *Rhagoletis batava* adults caught in different traps in 2015 and 2016.

In the Mecklenburg-Vorpommern region of Germany, the main flight period of sea buckthorn flies was from June 27th to July 14th [14]. In Lithuania, the peak flight period of these pests was significantly later and varied slightly between seasons. In 2015, the sea buckthorn flies were most abundant from July 27th to August 10th. During this period, the highest number of flies caught in yellow traps was an average of 193 specimens per trap. Meanwhile, in white traps, the highest recorded number of pests was 194 specimens per trap. From mid-August, the number of sea buckthorn flies caught in the traps began to decrease drastically, and by September, no specimens were recorded in either the yellow or white traps.

In the following growing season, the peak flight period of sea buckthorn flies was reached on August 7th, with an average of 76.8 specimens per yellow trap and 50.5 specimens per white trap. Notably, in 2016, the flight period of sea buckthorn flies lasted slightly longer, as a few adults were still recorded in the traps on September 9th. Finally, by mid-September, no specimens were observed in the traps.

Comparing the attractiveness of the different traps used in the experiment, the yellow traps were clearly superior. In 2015, the yellow traps attracted a total of 1155 specimens, or an average of 144.4 specimens per trap. Meanwhile, the white Delta traps caught a total of 949 specimens, or an average of 118.6 specimens per trap. In the following season, the yellow traps captured a total of 815 specimens, or an average of 101.9 specimens per trap. The white Delta traps were less attractive, capturing a total of 572 specimens, or an average of 71.5 specimens per trap. The superior attractiveness of the yellow traps to sea buckthorn flies was also confirmed by the results of other researchers [20; 8].

Almost all sea buckthorn orchards in Lithuania are grown organically. Therefore, the use of chemical insecticides is not possible. Additionally, reducing the practise of chemical plant protection products is undoubtedly a positive goal. As an alternative to synthetic insecticides, biological products can be used

[24; 8]. Since part of the sea buckthorn fly's life cycle is spent in the soil, the possibility of using entomopathogenic nematodes for pest control seems very realistic. A biological plant protection product with invasive second-stage juveniles of *Steinernema carpocapsae* was used against the *Rh. batava* pupae overwintering in the soil. The product suspension was applied to the areas under the sea buckthorn trees, which had previously been well isolated under insectary cages. Höhne and Kuhnke [14] used similar devices in their studies with *Rh. batava*.

The number and abundance dynamics of adult sea buckthorn flies caught in an isolated environment after using a biological plant protection product with invasive juveniles of *Steinernema carpocapsae* are presented in Fig. 2. The entomopathogenic nematode suspension was used in two concentrations – 0.5 million J2 per square meter and 1.0 million J2 per square meter of soil surface. The appearance of sea buckthorn fly adults in the isolated environment fully matched the beginning and peak of fly activity in the plantations.

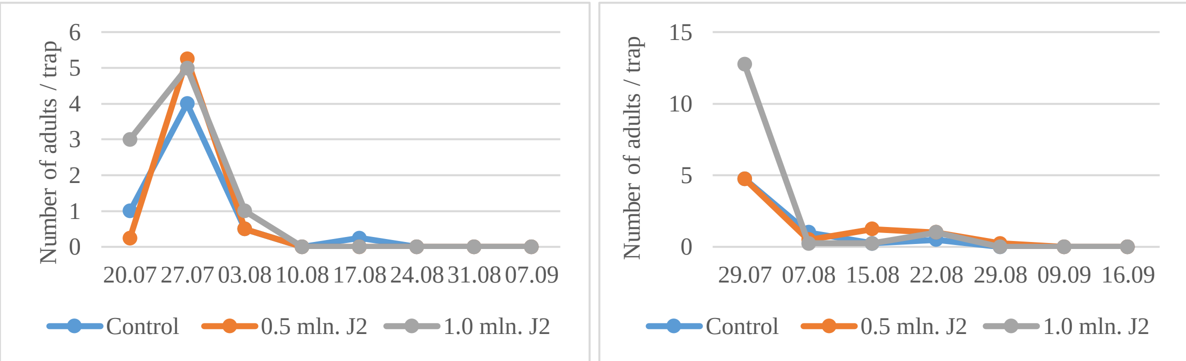


Fig. 2. The number and abundance dynamics of *Rhagoletis batava* adults in an isolated environment after application of biological plant protection product in 2015 and 2016.

The first emerged adult pests in the isolated environment were observed in mid-July 2015. In the following season, the first specimens were detected at the end of July. The highest number of adult sea buckthorn flies in the insectary cages was found at the end of July. Additionally, in the isolated environment, the last pest specimens were detected in mid-August 2015 and at the end of August 2016.

However, when assessing the impact of the biological plant protection product on the abundance of emerged adult sea buckthorn flies, it must be acknowledged that the product was not effective in either of the study seasons. Compared to the control variant, where the soil surface was watered with clean water, the other test variants, where the soil surface was treated with suspensions of the biological plant protection product at different concentrations, usually had a higher number of detected adult sea buckthorn flies.

There are not many publications on the use of biological plant protection products for controlling sea buckthorn flies, and none at all on the possibilities of using entomopathogenic nematodes for this purpose. However, laboratory study results have been published involving entomopathogenic nematodes against the cherry fly *Rh. cerasi* [25]. In these studies, third-instar cherry fly larvae were infested with different species of entomopathogenic nematodes. The results showed a certain, albeit unreliable, positive effect. Nevertheless, the results of an experiment conducted within the framework of the European COST 850 project were absolutely disappointing [13]. The experiment was also carried out with third-instar cherry fly larvae, which were infested with invasive juveniles of 18 different entomopathogenic nematode species. However, the mortality rate of the pest larvae was very low. Therefore, the researchers concluded that due to the limited time and different spatial activity, the potential of entomopathogenic nematodes for controlling *Rh. cerasi* is quite small.

The experiment to use entomopathogenic nematodes for the control of *Rh. batava* was conducted under field conditions. Additionally, the biological plant protection product was applied during the pupal stage of the sea buckthorn fly. The pupae of the sea buckthorn fly are compact, enclosed, and almost without any natural openings. Therefore, it is believed that there are no opportunities for the entomopathogenic nematodes to penetrate the pupal interior. Koppler et al. [25] stated that entomopathogenic nematodes cannot infest cherry fly pupae. Since the pupae of the sea buckthorn fly and the cherry fly are very similar in structure, the use of the biological product *Steinernema carpocapsae* against the sea buckthorn fly was not successful.

To achieve maximum effectiveness of various plant protection measures and to reduce the use of synthetic products, pheromones and other semiochemicals are very important [16; 21; 24; 8]. These substances are becoming increasingly significant not only for pest monitoring but, with improved availability, can also be used for direct pest control. The pheromone (-)-δ-heptalactone was used to attract adult sea buckthorn flies to McPhail-type traps. It was first discovered through gas chromatography-mass spectrometry analysis that this substance is released specifically by male sea buckthorn flies [21]. According to the authors of this study, significantly more sea buckthorn flies were caught in traps with (-)-δ-heptalactone used in field trials than in those without the pheromone. However, there is a lack of information on the most attractive and cost-effective dose of (-)-δ-heptalactone for adult sea buckthorn flies. Five different pheromone doses were selected for the study. The results obtained during the study are presented in Fig. 3. During the first assessment, the lowest pheromone dose of 6 μL showed significantly the best result, attracting 1.5 times more flies compared to the control. The 15 μL pheromone dose was the least attractive, while the 25 μL, 50 μL, and 75 μL doses of (-)-δ-heptalactone were equally attractive to the sea buckthorn fly and did not differ from the control.

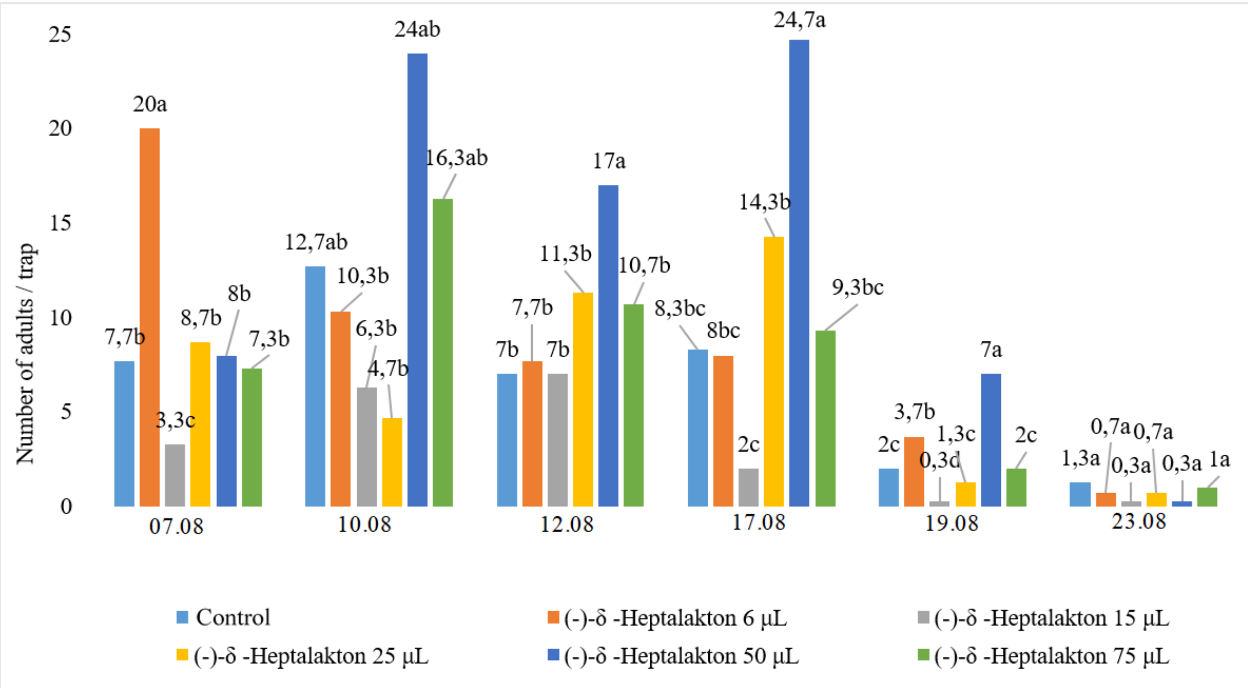


Fig. 3. Attraction of different doses of the pheromone (-)-δ-heptalactone to adult *Rhagoletis batava*

Note: Differences between means marked with different letters are significant (P≤0.05).

During the second assessment, the number of adult sea buckthorn flies captured in McPhail traps with different doses of the pheromone did not differ significantly from the control. Although traps with 50 μL and 75 μL doses of (-)-δ-heptalactone attracted the highest numbers of pests. In the third count, the 50 μL (-)-δ-heptalactone dose stood out for its attractiveness. All other traps did not significantly differ in the number of attracted sea buckthorn flies compared to the control. During the fourth assessment of the attractiveness of different doses of (-)-δ-heptalactone, the 50 μL dose again demonstrated the best result. The pheromone traps with other doses, including the highest 75 μL dose, did not perform well, and the results did not differ significantly from the control. Analysis of the trap contents on August 19th showed that the activity of sea buckthorn flies was decreasing. Only 2 individuals were found in the control traps. However, among the pheromone traps, the 50 μL (-)-δ-heptalactone dose again provided the best result. Finally, in the last assessment conducted on August 23rd, only a few specimens were found in the traps, and no significant differences between the different treatments were observed.

Throughout the study, a total of 832 sea buckthorn flies were captured, with 92 specimens in the control traps, 151 specimens in traps with 6 μL of (-)-δ-heptalactone, 58 specimens in traps with 15 μL of (-)-δ-heptalactone, 123 specimens in traps with 25 μL of (-)-δ-heptalactone, 243 specimens in traps with 50 μL of (-)-δ-heptalactone, and 165 specimens in traps with 75 μL of (-)-δ-heptalactone.

To attract *Rh. batava* adults to the traps, the best results were achieved using traps lured with 50 μL of (-)-δ-heptalactone. V. Būda and team [21] used a 25 μL dose of (-)-δ-heptalactone in their effectiveness studies in sea buckthorn plantations. Compared to the control, the pheromone attracted significantly more sea buckthorn flies.

CONCLUSIONS

The first adults of sea buckthorn fly were detected in the traps during the last decade of July. The peak of these pests' flight activity was observed during the last decade of July and the first decade of August. Yellow traps were significantly more attractive to sea buckthorn flies than white Delta traps. The use of the biological product *Steinernema carpocapsae* against the sea buckthorn fly proved ineffective. In the pheromone traps, the best attractant for sea buckthorn flies was the pheromone (-)-δ-heptalactone used at a dose of 50 μL.

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