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Increased occurrence of five Noctuidae species in Slovenia in the period 2019-2022: presentation of the species and preliminary results of their occurrence and damage

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Increased occurrence of five Noctuidae species in Slovenia in the period 2019-2022: presentation of the species and preliminary results of their occurrence and damage

Abstract: In this paper, we present five species of owlet moths (Noctuidae), whose greater abundance was found in Slovenia in the period 2019-2022 as part of research and expert work in the field of plant protection. The greatest economic importance is attributed to the tomato looper (*Chrysodeixis chalcites*), which two years after its first strong appearance on the Slovenian coastal area is already causing major problems for tomato growers. We did not confirm the harmfulness of the caterpillars on cultivated plants for the silver-Y moth (*Autographa gamma*), the adult males of which are caught in large numbers using pheromone traps in central Slovenia, and the less numerous beet armyworm (*Spodoptera exigua*). We can confirm the same for the shark moth (*Cucullia umbratica*), whose adult males are caught in pheromone traps of the EU quarantine pest *Spodoptera frugiperda* and the copper underwing (*Amphipyra pyramidea*), for which we suggest the Slovenian name 'bakreni podkrilec', which appeared in, on or in the immediate vicinity of the pheromone traps of the spongy moth (*Lymantria dispar*) in the oak-hornbeam forest in Prekmurje.

Key words: Noctuidae, *Chrysodeixis chalcites*, *Autographa gamma*, *Spodoptera exigua*, *Cucullia umbratica*, *Amphipyra pyramidea*, Slovenia

Številčnejši pojav petih vrst sovk (Noctuidae) v Sloveniji v obdobju 2019-2022: predstavitev vrst in preliminarni rezultati njihovega pojavljanja in škodljivosti

Izvleček: V prispevku predstavljamo pet vrst sovk (Noctuidae), katerih večjo številčnost smo v Sloveniji ugotovili v obdobju 2019-2022 v okviru raziskovalnega in strokovnega dela na področju varstva rastlin. Največji gospodarski pomen pripisujemo paradižnikovi sovki (*Chrysodeixis chalcites*), ki dve leti po prvem močnejšem pojavu v Slovenski Istri že povzroča večje težave pridelovalcem paradižnika. Za glagolko (*Autographa gamma*), katere samci se v feromonske vabe v osrednji Sloveniji lovijo v velikih številih in manj številčno pesno sovko (*Spodoptera exigua*), nismo potrdili škodljivosti gosenic na gojenih rastlinah. Podobno lahko potrdimo tudi za škrbinkinega meniha (*Cucullia umbratica*), katerega odrasli samci se lovijo v feromonske vabe karantenske sovke *Spodoptera frugiperda* in sovko *Amphipyra pyramidea*, za katero predlagamo slovensko ime ‚bakreni podkrilec', ki se je pojavljal v, na ali v neposredni bližini feromonskih pasti gobarja (*Lymantria dispar*) v hrastovo-gabrovem gozdu v Prekmurju.

Ključne besede: Noctuidae; *Chrysodeixis chalcites; Autographa gamma*, *Spodoptera exigua*, *Cucullia umbratica*, *Amphipyra pyramidea*, Slovenija

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1 INTRODUCTION

Noctuidae is the second largest family in the superfamily Noctuoidea, with about 1,089 genera and 11,772 species (Zhang, 2011; Simonović et al., 2020). In Slovenia only some Noctuidae species are occasionally important pests of cultivated plants, for example three species from the genus *Agrotis*, which are known as soil pests, and *Mamestra brassicae* (L., 1758), *Lacanobia oleracea* (L., 1758) and *Helicoverpa armigera* (Hübner, [1808]), which caterpillars feed with the aboveground parts of the plants (Devetak et al., 2010). More than 300 Noctuidae species occur in Slovenia (Database of invertebrate pictures, 2022), which means that about 2 % of them are pests of cultivated plants.

In our research and expert work over the past three years, we have become aware of the more massive occurrence of five Noctuidae species, which could become economically important in the future due to climate change, the extension of agricultural production as well as the fact that most noctuids are polyphagous and at a certain moment they can find certain plant species as more suitable host and attack it more strongly than other host species.

In the paper we present *Spodoptera exigua* (Hübner, [1808]), *Chrysodeixis chalcites* (Esper, 1789), *Autographa gamma* (L., 1758), *Amphipyra pyramidea* (L., 1758) and *Cuculia umbratica* (L., 1758), whose massive occurrence has been recorded in the Slovenian agricultural or forest environment since 2020, but have never been described in details until now.

2 DESCRIPTION OF FIVE SPECIES OF Noctuidae

2.1 BEET ARMYWORM / SMALL MOTTLED WILLOW MOTH (*Spodoptera exigua* [Hübner])

Spodoptera exigua (Hübner) is a tropical insect native to Southeast Asia (Capinera, 2008), and presently found in all continents, except on Antarctica (Falsafi et al., 2022). It was named (sugar) beet armyworm, because it colonized sugar beet plantations in America around the late 1800s and early 1900s (Wilson, 1932). Nowadays this species is present in most countries in Asia, Africa, Europe, North America, and Oceania (CABI, 2022a). Particularly in Europe, *S. exigua* has been reported to feed in some important crops from the family Solanaceae and Cucurbitaceae, and also in some other plants such as asparagus (*Asparagus officinalis* L.) and cotton (*Gossypium* spp.) (EPPO, 2022). Larvae of this insect feed on young leaves and fruits and might skeletonize foliage. They like to form a colony while feeding and as they mature, they become more solitary and cause large, irregular holes in foliage (Capinera, 2008).

The adult of *S. exigua* (Figure 1.1) is a moth of moderate size, with a wingspan measuring 25–30 mm. The forewings are colored grayish brown while the hind wings are usually gray or white color with a black line at the margins. The eggs are deposited in a clump of 50–250 eggs, colored white or greenish white, and covered with whitish scales that has a cotton-like appearance. The individual egg looks circular from above, but the top looks a little pointy from the side. Normally, there are five stages of instar. The larvae are pale green to yellow during the first two stages, and they obtain strips on the dorsal as they mature. In the last (fifth) stage larvae have variety in their appearance, with the most common ones being green dorsally with pink or yellow color ventrally and white stripe laterally. Pupation occurs in the soil at

Figure 1.1: Adult of *Spodoptera exigua* (photo: Dejan V. Stojanović)

Figure 1.2: First male adults of *Spodoptera exigua* caught in the pheromone traps in Ljubljana in 2022 (photo: Stanislav Trdan)

around 1 cm from the soil surface. The pupa color is light brown and 15–20 mm in length (Capinera, 2008).

Life cycle of *S. exigua* can be completed in 24 days, and six completed cycles can be achieved in a warm location such as Florida. The eggs hatch in 2–3 days in warm summer and took longer when it is cold, with the development threshold around 12.4 °C. The duration for each instar stage varies between 1 to 3 days, depending on the temperature, with the threshold around 13.6 °C. On summer days the duration of the pupal stage is 5–7 days (Capinera, 2008). Maharjan et al. (2022) reported that the total time for each stage of development decreased between the temperature of 15–35 °C, and that the eggs failed to hatch in the temperature above that range. As for the adaptation to the colder temperature, Zheng et al. (2011) concluded that *S. exigua* can either migrate to the warmer place or overwinter the season with hibernation.

So far, not enough data are available for its bionomics in Slovenia, therefore in 2022 we have started the monitoring of this insect at the Laboratory Field of Biotechnical Faculty in Ljubljana. At the second half of April, we have placed three pheromone traps (producer: CSalomon, Budapest, Hungary). The first adults (Figure 1.2) were captured in the traps in the middle of June, and in the beginning of October last adults were found in the traps. During this period, 40 males were caught in the traps, of which the maximum was in the first two weeks of July (0.4 males/trap/day). Since 2015 *Spodoptera exigua* is being mentioned also in Technological guidelines for integrated vegetable production (2015). Its occurrence in Slovenia has been also reported at collection at Slovenian Museum of Natural History (Database of invertebrate pictures, 2022). In 2015 Jež et al. reported the occurrence of *S. exigua* in Goriška Brda and Pohorje, while in 2018, Gomboc and Zakšek (2018) reported the occurrence of *Spodoptera exigua* in Ljubljana. In Slovenia, we have not yet recorded information about the greater harmfulness of this noctuid in agricultural production, however, we must pay attention to this species in the future, as increasingly pronounced climate changes and the reduction in the number of insecticides for its suppression could be the causes of its greater economic importance.

2.2 TOMATO LOOPER / GOLDEN TWIN-SPOT MOTH (*Chrysodeixis chalcites* [Esper])

Chrysodeixis chalcites (Esper) is a native species in the area between 45 °N and 35 °S, which is including southern Europe, the Mediterranean, the Middle East, and southern Africa, and now its distribution has been reaching some countries in Oceania, North America, and South America. This species is present in northern Europe, but winter mortality prevents its establishment outside this area. However, it has managed to extend its distribution area in southern Europe by establishing greenhouse areas. Nowadays, with global trading, the risk of its distribution is also increasing with the international transport of its host plants (CABI, 2022b). Larvae mostly fed on leaves and sometimes also on flowers, and the main host are including vegetables like tomatoes (*Solanum lycopersicum* L.), cultivated plants of *Brassica oleracea* L., pepper (*Capsicum annuum* L.), and sweet potatoes (*Ipomoea batatas* [L.] Lam.), and ornamental plants like pelargonium, amaryllis, and hosta (Simonović et al.,2020). Early larvae feed on the bottom surface of leaves and leave upper leaf cuticles as a whole, while later larvae eat all parts of leaves (Munippan, 2012).

The adult moth (Figure 2.1) has a moderate size, with a wingspan measuring 32-37 mm and a body length of around 20 mm. The forewings are golden brown, with two oval silver freckles, approximately the same size, in the central part. The hindwings are brownish-gray, darker toward the outer edge, with distinctive dark gray veins. The male has two tufts of black hair at the end of the abdomen, while in the female moth this characteristic is missing (Simonović et al., 2020). The larvae have twelve legs, and their color is pale green and darker on the back, with some white lines and dots along the body. The pupa is enclosed between two dead leaves on or near the ground and surrounded by a cocoon of white silk (Hudson, 2022).

Eggs are laid singly onsite of leaves and hatch in 3–4 days, and each female can lay up to 200 eggs. There

Figure 2.1: Adult of *Chrysodeixis chalcites* (photo: Dejan V. Stojanović)

are five larval instars with around 13 days total larval period. The adult moth takes 7 days to emerge from the cocoon (Muniappan et al., 2012). In nature with favourable conditions, nine generations per year were recorded (Harakly and Farag, 1975). The temperature thresholds for the development of eggs, larvae, and pupae are 4.8, 2.7, and 4.6 °C, respectively. The length of one life cycle, starting from the incubation period of eggs until the end of pupation, is recorded at 60.4 days at 20 °C, and 37.4 days at 30 °C (Abd Allah, 2013).

We first recorded adults of *C. chalcites* in 2020 within surveillance of *Spodoptera frugiperda*, an EU A1 quarantine pest. Greater injuries caused by feeding of caterpillars and caterpillars itself were detected in 2021 on tomato leaves in greenhouses in the Slovenian Coast (wider area of Koper, Western Slovenia, Figure 2.2) in late summer. In Slovenia, the species was recorded in 2001 for the first time (Lesar, 2001), but then for nearly twenty years there were no reports of its harmfulness. In the past two years, the pest has been reported to occur in tomato greenhouses almost all over the country. Therefore we have started with its monitoring in 2022 at two different areas, Western Slovenia (Dekani) and Central Slovenia (Laboratory Field of Biotechnical Faculty, Ljubljana). 3 pheromone traps (producer: Russel IPM Ltd, Flintshire, United Kingdom) were placed at each of selected areas. In Dekani the first males were recorded in the traps in the end of May, and the peak was established in August with almost 10 males/trap/day. In Ljubljana, the first males were caught in the traps in July 20 and at the time this article was submitted for publication (end of October 2022), an average of two males were caught in the traps per day. This data represents one of the two peaks of occurrence of the pest in Ljubljana, where the first peak with the same number of males (2/trap/day) was reached in mid-August.

Figure 2.2: Strong attack of *Chrysodeixis chalcoides* caterpillars in the tomato leaves in Dekani (Slovenian Coast) in September 02 2021 (photo: Stanislav Trdan)

2.3 SILVER-Y MOTH (*Autographa gamma* [L.])

Autographa gamma (L.) is an important pest widespread throughout Europe, Asia, northern Africa, and some countries in north and south America. It has around 300 host plants known with some of them being important crops. It mainly spreads through population migration and international transport of plant materials (CABI, 2022c). Its main hosts are sugar beets, lettuces, cabbages, tomatoes, potatoes, beans, and peas. The larvae feed on leaves and can skeletonize the leaves, and as they mature, the older caterpillars can eat the whole leaves. When there is a population explosion of *A. gamma,* the whole crops can be easily destroyed (Hill, 1987).

Female moths lay eggs at the bottom of the leaf surface of low-growing plants, either singularly or in a lump of a few eggs. The eggs are round, ribbed, and white. The larvae are 'semi looper', with two pairs of abdominal legs. The larvae are usually colored green with a darker color in the back, dorsal white line, and yellow lateral line. On maturity, larvae reach the size of 20–30 mm, then started pupation. The pupas are black and wrapped in a silk-like cocoon. The adult moths (Figure 3.1) are grey with some darker patterns and distinctive silvery gamma (**γ**) shaped in the middle of both forewings. The wingspan measures 35–48 mm (Hill, 1987).

Depending on the location, this moth can make up to four generations in one year. The moth is known as a good migrant, and it favours warm and moist conditions. The optimum temperature for larvae is 23–30 °C, around 25 °C for pupae, and 20–25 °C for the moth, and the optimum humidity is 80–95 % (Chumakov and Kuznetova, 2022). One female moth can lay 500–1000 eggs in the

Figure 3.1: Adult of *Autographa gamma* (photo: Dejan V. Stojanović)

Figure 3.2: Numerous catch of *Autographa gamma* males in pheromone trap in Ljubljana in 2019 (photo: Stanislav Trdan)

Figure 4.1: Adult of *Amphipyra pyramidea* (photo: Dejan V. Stojanović)

whole season. After 10–12 days, the eggs hatch into larvae. Larvae develop for around 3–4 weeks before dropping into the soil and starting the pupation period, which lasts 10–14 days (Hill, 1987).

While the larvae are mostly feeding during the night, the adult moths are mostly active at dusk and feed on the nectar in the flowers of many wild-growing and cultivated plants. Under favourable conditions, breeding continues, but most adults reared in northern Europe migrate south to a warmer area (Alford, 2012).

In Ljubljana, this moth completed three generations in 2019 (April–October) and 2020 (April–November), with the peak of population happening when plants were in full growth. It was also proven that population dynamics are influenced by temperature, humidity, rainfall, and solar radiation (Gornik, 2021). This was the first study known for Slovenia, and it was based on pheromone dispensors and pheromone traps (VARL+) produced by CSALOMON® (Budapest, Hungary). Despite the large number of males (2019: a total of 418 or maximum daily catch/trap of 3.4 males in the middle of July; 2020: a total of 594 or max daily catch/trap of 3.3 males in the end of April) caught in the traps (Figure 3.2), we did not find any major injuries on its hosts in the immediate vicinity of the traps.

2.4 COPPER UNDERWING (*Amphipyra pyramidea* [L.])

Amphipyra pyramidea (L.) (Figure 4.1) is a common moth recorded from up to 50 species of deciduous trees and bushes and is very commonly attacking pedunculate oak *(Quercus robur* L.*)*. The species hibernate as an egg in winter, and then hatches in spring and is fed on foliage (Roslin and Salminen, 2009). Some of its alternative hosts are ash tree (*Fraxinus* spp.), privet (*Ligustrum* spp.), honeysuckle (*Lonicera* spp.), apple (*Malus* spp.), *Rhododendron* spp, and roses (GBIF, 2022a). According to CABI (2022d) this moth is present in some countries in Asia and Europe.

The fully grown larvae are plump with green or whitish green colored with white or pale yellow dots. The body consisted of eight abdominal parts that measure up to 45 mm long. It has three incomplete lines, one along the back and one along each left and right side. Adults are longer than larvae (45–55 mm) and have brownish forewings with black or pale yellow marks, while the hind wings are coppery red (Alford, 2012).

It is a univoltine species, meaning that it produces only one brood in the season. Eggs started to hatch in June and can be as late as October (GBIF, 2022a). The adult moths are attracted to sugar and light, and from August until October they are rearing around and inhabit woodland, parkland, and hedgerow (Skinner and Wilson, 2009).

Amphipyra pyramidea has been detected in Slovenia in 1993 for the first time (Titovšek, 1993), and so far, no major damage caused by the larvae has been recorded in the country. The copper underwing is considered as an interesting nocturnal butterfly, as mentioned by Jež et al. (2015). In 2022, we have detected massive occurrence of *A. pyramidea* in the pheromone traps for monitoring the males of spongy moth (*Lymantria dispar* L.) within the LIFE eGYMER research project (funded by EU in the period 2021-2024). We have placed different types of pheromone traps containing pheromone dispensor, produced by CSalomon (Budapest, Hungary), into the forest Ginjevec near Slovenian border with Hungary. The dominant tree species in the forest Ginjevec are oak (*Quercus* spp.) and European hornbeam (*Carpinus betulus* L.). The first adult males of copper underwing in or on (Figure 4.2) the traps or their immediate vicinity was recorded in last 10-day period of June, and they also appeared during the

Figure 4.2: Adult male of *Amphipyra pyramidea* on the pheromone trap for the monitoring of *Lymantria dispar* in the forest Ginjevec (NE Slovenia), August 17 2022 (photo: Stanislav Trdan)

last inspection of the traps (September 01 2022). Males were caught on pheromone traps in the highest numbers from the beginning of July to the beginning of August, when we found more than 1 male/trap/day in five consecutive 7-day intervals. We did not notice injuries from caterpillars on the deciduous trees caused by the caterpillars of *A. pyramidea*, but it is true that our attention was mainly focused on monitoring of the spongy moth.

2.5 SHARK MOTH (*Cuculia umbratica* [L.])

Cuculia umbratica (L.) is present in some countries in Asia, Europe, and North America (CABI, 2022e). The caterpillars, which emerge from the eggs laid on the leaves of lettuce *(Lactuca* spp.) and sowthistle (*Sonchus* spp.), devour the leaves of these species and can cause great injury to the plants (Newman, 1869).

The moth (Figure 5.1) is fairly big, with a wingspan measuring 52–59 mm (Skinner and Wilson, 2013). The forewings color is smokey-gray with a slender but very distinctive black line from the middle of the base to the middle of the wing. The wing rays are also black but the fringe is lighter. The hindwing's color is also smokey-gray, with the wing rays darker and the base paler. The head is smokey black while the thorax and body are smokey-gray (Newman, 1869).

The moth is known as single brooded and not migrating. It overwinters as a pupa and starts emerging every year around June to July, inhabiting waste ground, sandhills, shingle beaches, marshy places, and gardens. Larvae cause a problem around late July to September. They feed at night and hide during the day under the leaves of the bottom plant canopy. Comes regularly to light and is attracted to various flowers, for example

Figure 5.1: Adult of *Cucullia umbratica* (photo: Dejan V. Stojanović)

honeysuckle (*Lonicera* spp.), sweet-william (*Dianthus barbatus* L.), valerians (*Valeriana officinalis* L.), and thistles (group of flowering plants characterised by leaves with sharp prickles on the margins, mostly in the family Asteraceae) (Skinner and Wilson, 2013). Until now, it is not presented as important agricultural insect pest.

The results of the occurrence of *Cucullia umbratica* in Slovenia in the period 2011-2013 are given by Jež et al. (2015). They found that the butterfly occurs in different areas of Slovenia, from Goriška Brda to Slovenske Gorice and Pohorje. In Slovenian coastal region, massive occurrence of *Cuculia umbratica* was confirmed in 2020 for the first time. Massive occurrence was recorded with pheromone traps (Figure 5.2) for surveillance of *Spodoptera frugiperda*. Pheromone dispensors and pheromone traps (funnel trap [green lid/green funnel/transparent bucket]) were produced by Pherobank (Belgium). Within survey of *S. frugiperda* in 2022, in Slovenian Coastal area and central Slovenia the first males of *C. umbratica* was re-

Figure 5.2: Four adult males of *Cucullia umbratica* in the pheromone trap for the monitoring of *Spodoptera frugiperda*, Sečovlje (Slovenian coast), July 17 2020 (photo: Stanislav Trdan)

corded in pheromone traps since the first half of May. By the end of August, a total of 150 males were caught in three baits in Ljubljana, with two peaks (the last week of May and the beginning of August), when on average almost 1 male/bait/day was caught in the baits. Despite the large number of males caught in pheromone traps, we did not find any damage due to the feeding of caterpillars on the cultivated plants.

3 CONCLUSIONS

In this article, we present five species of owlet moths that we have been paying attention to since 2020, when in our research and expert work we found some cases of increased occurrence of butterflies or injuries due to feeding caterpillars. In connection with the latter statement and as potentially the most important pest among the five species, we highlight the tomato looper (*Chrysodeixis chalcites*), which occur in Slovenia for at least 20 years, but we found a greater extent of damage on tomato leaves, which the caterpillars feed on, in greenhouses in the Slovenian coastal area in 2021. In 2022, the occurrence of this pest on tomatoes in greenhouses was also reported from other areas of Slovenia, even from Prekmurje (NE Slovenia). Currently, the search for suitable solutions to limit the spread and harmfulness of this greenhouse pest is among the priorities of phytomedical experts and tomato growers. In some European countries, the pest is already effectively controlled with egg parasitoids from the genus *Trichogramma* (Polaszek et al., 2012) and *C. chalcites* nucleopolyhedrovirus (Bernal et al., 2018) and these or other biological control agents should be considered for implementation in our country for reducing the economic importance of this pest.

In the period 2019-2020, silver-Y moth (*Autographa gamma*) was caught on a very large scale using pheromone traps in central Slovenia, but interestingly, we did not notice any major damage to the cultivated plants, which these extremely polyphagous caterpillars normally feed on. We did not find any records on the bionomics and harmfulness of beet armyworm (*Spodoptera exigua*) in Slovenia, so in 2022 we decided to study its seasonal dynamics in central Slovenia. Males were caught in traps from mid-June 2022 onwards, but in relatively small numbers, and even for this species we have not yet confirmed the harmfulness of caterpillars on cultivated plants.

Since 2020, we have identified a significant number of captured adult males of the shark moth (*Cucullia umbratica*) in pheromone traps for fall armyworm (*Spodoptera frugiperda*) on the Slovenian coast, but we have not found damage caused by caterpillars on cultivated plants, for example on lettuce. The reason for this may be the fact that we have set up pheromone traps right next to greenhouses with monoculture tomato production, near which there is otherwise a fairly widespread sowthistle (*Sonchus* spp.), the leaves of which the caterpillars like to feed on. We were surprised by the continuous appearance of copper underwing (*Amphipyra pyramidea*) in the oak-hornbeam forest in Prekmurje, namely in, on or in the immediate vicinity of pheromone traps for monitoring spongy moth (*Lymantria dispar*). They are species from different families, as the spongy moth belongs to the Erebidae family. And perhaps the results of our research indicate a greater relationship between the species *Amphipyra pyramidea* and *Lymantria dispar* than their current taxonomic classification otherwise indicates.

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