ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 72 1 Number 1-2, 2024

SPECIES SPECTRUM AND ABUNDANCE OF MOTHS (LEPIDOPTERA) IN THE GREENHOUSE CULTURE OF *SOLANUM LYCOPERSICUM*

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Link to this article: https://doi.org/10.11118/actaun.2024.001
Received: 20. 11. 2023, Accepted: 8. 1. 2024

Abstract

The species spectrum and abundance of moths were monitored in a greenhouse in Kameničany (western Slovakia) in 2020, in which *Solanum lycopersicum* was grown from seedlings imported from the Netherlands. Moths were caught using light traps placed at different sites in two sections of the greenhouse, a part with continuous cultivation and a part with culture restoration during research. Captures were taken during June, October and November. A total of 836 individuals of 87 species from 14 families were recorded. Of the moths captured, 12 species (99 individuals) were saprophagous, 45 species (624 individuals) were specialists not developing on Solanaceae, 9 species (22 individuals) were polyphagous on herbs or woody plants with unlikely developments on Solanaceae, 14 species (68 individuals) were polyphagous which development on tomato is possible, and 7 species (23 individuals) were polyphagous that could damage tomato plants. All of these 7 potential pests were native owlet moths (Noctuidae) that penetrated into the greenhouse from the surrounding area. None of these species was recorded in numbers to indicate their harmfulness. No species were found that may have been introduced with the seedlings.

Keywords: greenhouse, tomato, moths, pests, central Europe

INTRODUCTION

The extent of covered areas for growing tomatoes is increasing. This is due to year-round consumer demand. In Czechia, for example, the covered areas have increased from 21 to 69 ha from 2015 to the present because of investment support (Němcová and Buchtová, 2021). In the context of the requirements of commercial chains for reduced permissible limits of pesticide residues and continuous harvesting, the most appropriate pest control is mainly based on bioagents and biological preparations.

Some species of polyphagous owlet moths (Noctuidae) are considered occasional pests of tomato, which can damage tomato in outdoor environments and can also invade greenhouses, e.g. *Mamestra brassicae* (Linnaeus, 1758), *Lacanobia oleracea* (Linnaeus, 1758), and *Phlogophora meticulosa* (Linnaeus, 1758). If females lay eggs on tomato plants in higher numbers, the caterpillars can cause more significant damage in a sudden manner (Marek and Vaňurová, 1995). Marek and Navrátilová (1995) published the black cotton caterpillar – *Helicoverpa armigera* (Hübner, 1808) as a “new pest of greenhouse tomatoes”. This polyphagous migrant occurs irregularly in central Europe with varying abundance and the possibility of entering greenhouses and causing damage is rather random. It is considered to be a major pest

of tomato grown under field conditions in southern Slovakia and Hungary (Hluchý, 2004). In recent years, the caterpillars of the South American *Tuta absoluta* (Meyrick, 1917) and the Mediterranean to Afrotropical *Chrysodeixis chalcites* (Esper, 1789) have been repeatedly introduced with tomato seedlings (Březíková, 2014; Bártová and Marek, 2000). Both species can reach high abundances and cause significant damage in subsequent generations until eradication.

Records of moths in greenhouses with tomato crops tend to be published, if these species have caused damage or if this is their first finding (Šefrová and Laštůvka, 2005, 2023; Šefrová *et al*., 2023). The aim of this study was to find out which moth species are present in the greenhouse with tomato culture and to evaluate whether these species have entered the greenhouse from the external environment or have been introduced with the seedlings, what their feeding requirements are and their phytosanitary importance.

MATERIALS AND METHODS

Characteristics of the Experimental Area

The research was conducted in the greenhouse of Kameničany Farm in western Slovakia (48°59′48.482″N, 18°10′7.484″E) in 2020. The greenhouse is divided into two parts of 0.9 ha and 2 ha. These parts are separated by a glass wall and opaque foil. In 2020, two varieties of tomato, 'Axiany' (Axia Vegetable Seeds) and 'Sweetelle' (Syngenta), were grown in the form of grafted seedlings imported from the Netherlands. A smaller proportion of the plants was planted in August 2019 and discarded in July 2020, i.e. during the course of the research. A new stand was planted in August 2020. We refer to this part here as the "culture restoration section". The larger part of the greenhouse was planted in December 2019 and left until November 2020. This section was referred to as the "continuous cultivation section".

The plants were guided along stretched growing ropes and were grown in coir substrate, used as a suitable gardening substrate after harvesting tomatoes. Tomatoes were harvested manualy. Pest and plant health monitoring was carried out weekly. Against pests, a non-specialized predator, *Macrolophus pygmaeus* (Rambur, 1839), was introduced in the greenhouse at two dates, 4 and 6 weeks after planting in a dose of 2.5 individuals/m^2. Two parasitoid species, *Encarsia formosa* Gahan, 1924 and *Eretmocerus eremicus* Rose & Zolnerowich, 1997, were also applied against whiteflies during the season based on monitoring. Pollination of the plants was ensured by the introduction of the bumblebee – *Bombus terrestris* (Linnaeus, 1758). Synthetic pesticides are only marginally used, usually only during the termination of the stand as a measure against the spread of pests to the new planting. The greenhouse is surrounded by fields on three sides, where wheat and barley were grown in 2020. On one side there are houses with gardens adjacent to the greenhouse. Insects can be introduced into the greenhouse with the seedlings or can enter from the surroundings through the air vents or the entrance door.

Sampling

Moths were captured using G21 GTS-30 light traps. Adults are baited with UV-A light, electrocuted on internal screens and captured in a trapping container. In both sections of the greenhouse (with culture recovery and with continuous cultivation), light traps were placed at three sites, at the far edge (FE), in the center of the greenhouse (C), and at the entrance edge (EE). The traps were set about 20 m apart, were suspended at a height of about 20 cm above the ground, and were operated during two periods, from June 1 to June 30 (30 days), and September 1 to November 12 (42 days). The two survey periods during the year were chosen to capture the peak of the growing season (peak insect activity and abundance) and the marginal part of the growing season when insect activity declines. The captured moths were collected on five dates, June 10, 25 and 30, October 16, and November 12. Moths were identified to species level and divided into five categories according to their feeding requirements:

- Sa – saprophagous species, developing on wilted plant parts and plant debris;
- Sp – trophic specialists (monophagous or oligophagous species), developing on plants within a genus or within a family other than Solanaceae, their development on the tomato and thus harmfulness is practically excluded;
- Po – polyphagous species, developing on various herbs and (or) woody plants, but development on Solanaceae is unlikely (it is not known), although it cannot be ruled out;
- Po+ – polyphagous species, occurrence on tomato is possible;
- Po++ – polyphagous species, harmful occurrence on tomato is known. The species occurrence constancy was calculated in the usual way, i.e. as the proportion of positive samples and the total number of samples (e.g. Odum, 1971).

RESULTS

Overall Results

A total of 87 species of moths from 14 families were caught in the greenhouse with the tomato culture, in total amount of 836 individuals. Tortricidae were the most rich family in terms of species (27 species). An overview of all moth families with numbers of species and individuals is shown in Tab. I. None of alien pest species that could be introduced with the seedlings have been recorded.

I: *Numbers of species and individuals of moth families found in 2020 in the Kameničany greenhouse; Czech family names are also given for practical reasons*

Family		Species	Individuals
Coleophoridae	pouzdrovníčkovití	1	1
Crambidae	travaříkovití	8	52
Erebidae	různobarvcovití	3	11
Gelechiidae	makadlovkovití	6	13
Geometridae	píďalkovití	15	28
Limacodidae	slimákovcovití	1	1
Noctuidae	můrovití	13	32
Oecophoridae	krásněnkovití	1	1
Plutellidae	zápředníčkovití	1	487
Pterophoridae	pernatuškovití	2	7
Pyralidae	zavíječovití	6	86
Tineidae	molovití	1	1
Tortricidae	obalečovití	27	113
Yponomeutidae	předivkovití	2	3
Σ		87	836

Tab. II shows 10 species with the highest abundance and constancy of occurrence. In all cases, these are common species that flew into the greenhouse from the surrounding area. None of them can harm the tomato. *Plutella xylostella*, the most abundant species and the species with the highest constancy, was registered in all samples, in June, October and November.

II: *10 moth species recorded in the highest abundance and constancy of occurrence*

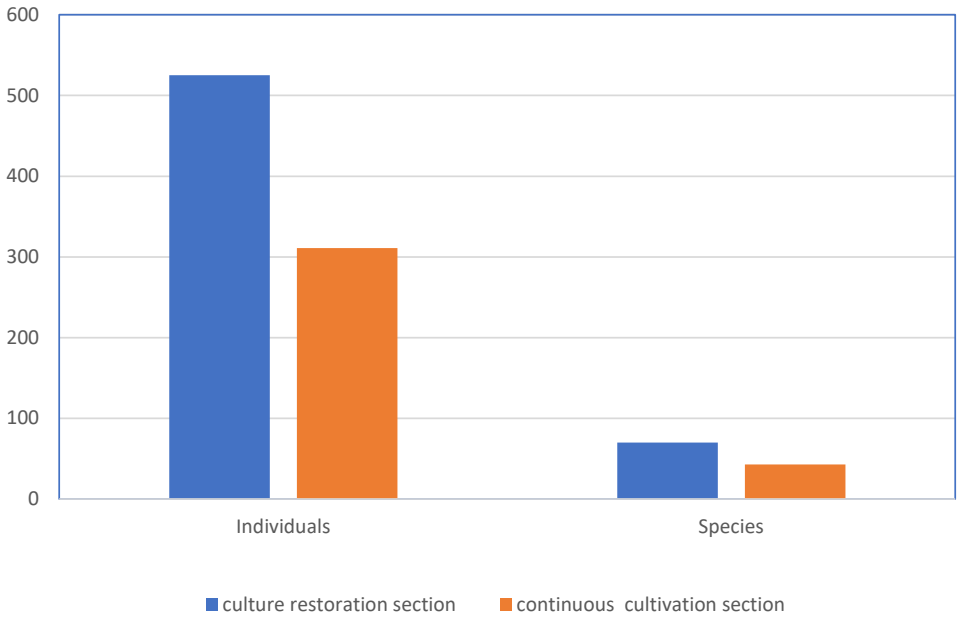
Species	Abundance	Constancy (%)
Plutella xylostella (Linnaeus)	487	47
Hypsopygia costalis (Fabricius)	78	43
Platytes cerussella (Den. & Schiff.)	35	33
Eana incanana (Stephens)	21	33
Hoplodrina ambigua (Den. & Schiff.)	11	27
Celypha rivulana (Scopoli)	10	20
Celypha rufana (Scopoli)	9	23
Eana canescana (Guenée)	9	10
Scopula immorata (Linnaeus)	8	17
Hedya nubiferana (Haworth)	8	13

Occurrence of Moths in Parts of the Greenhouse

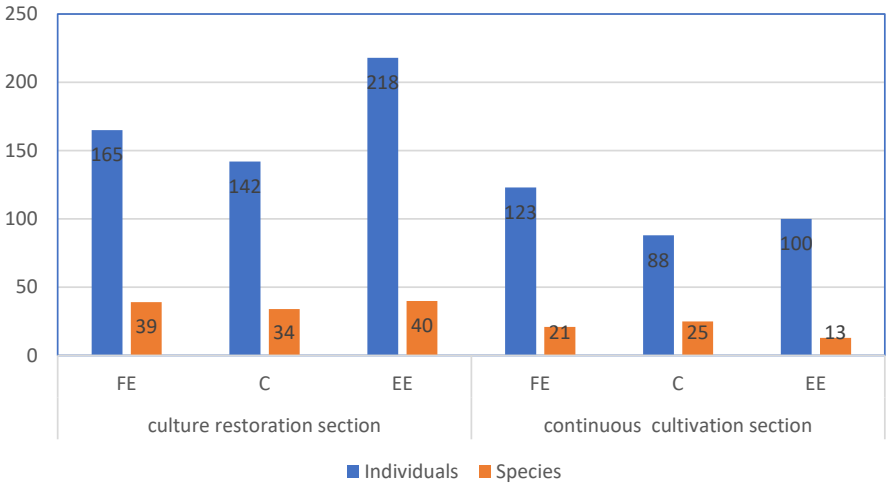
A total of 525 individuals (70 species) were catched in the culture restoration section of the greenhouse and 311 individuals (43 species) in the continuous cultivation section (Fig. 1).

Occurrence of Moths in Differently Placed Traps

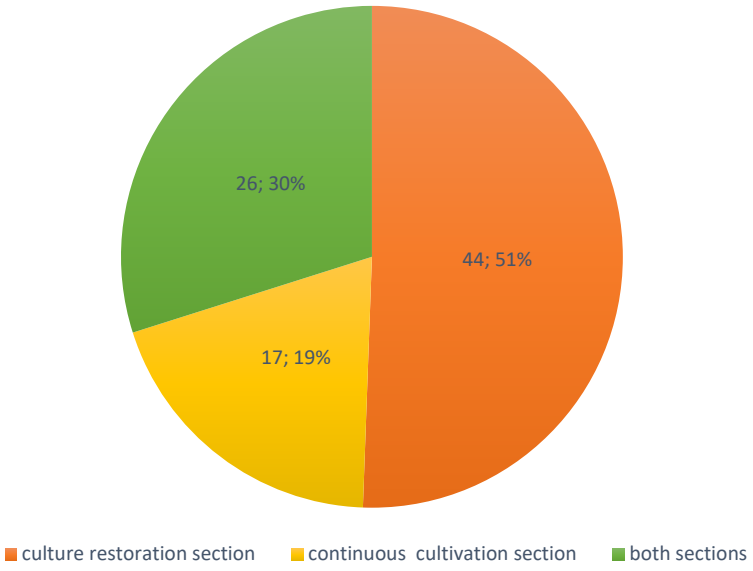
More individuals and species were caught in all three traps in the greenhouse part with the restoration culture than in the traps in the continuous culture part, against expectation. The trap located at the entrance edge (i.e. near the entrance door) had the highest number of species and individuals caught in the culture restoration section (40/318) (Fig. 2).



1: *Number of individuals and species of moths caught in the part of the greenhouse with culture restoration during the research and in the part with continuous cultivation*



2: *Numbers of individuals and species of moths caught in differently placed traps in both parts of the greenhouse; FE – far edge, C – centre, EE – entrance edge*



3: *Number of moth species caught exclusively in the culture restoration section, in the continuous culture section and in both sections of the greenhouse*

Altogether 44 species (51%) were caught exclusively in the culture restoration section of the greenhouse and 17 species (19%) in the continuous culture section. At the same time, 26 species (30%) were caught in both parts (Fig. 3).

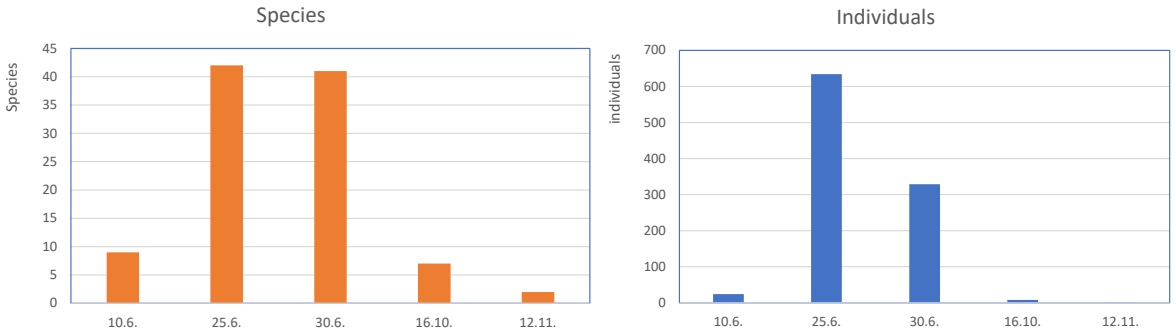
Occurrence of Moths Over Time

More individuals and species of moths were found in the sampling during June than in October and November. Most individuals (634) and species (42) were recorded in the 25 June sampling (Fig. 4).

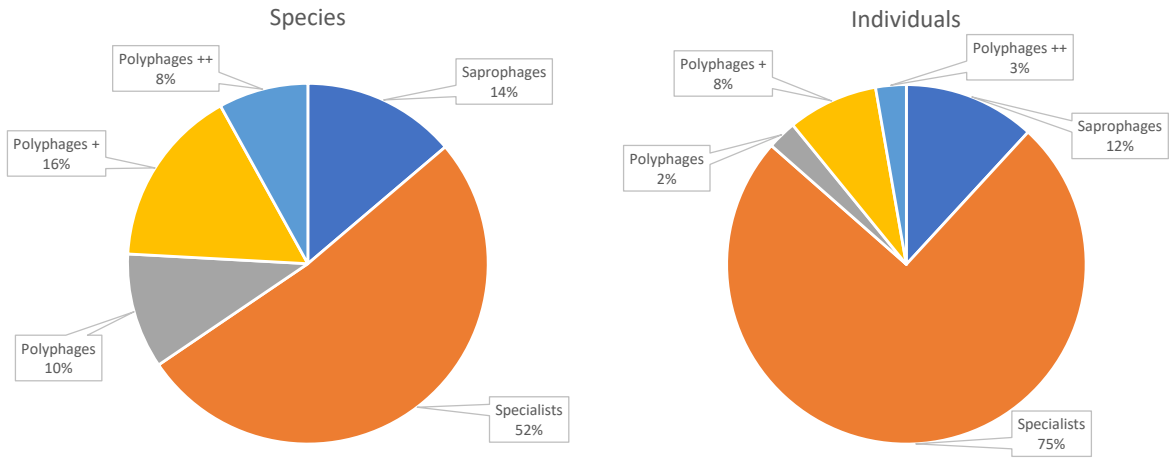
In June (during peak of growing season) an average of 33 individuals and 3 species were caught per day. In October and November (at the end of the growing season), it was 0.2 individuals and 0.2 species per day.

Food Spectrum of Caught Moth Species

Of the total number of moths caught, 12 species (99 individuals) were saprophages, 45 species (624 individuals, i.e. 75%) were specialists not developing on Solanaceae (cannot cause damage), 9 species (22 individuals) were polyphagous species that develop on herbs or woody plants, but as known other than Solanaceae, and 14 species (68 individuals) were polyphagous species that can occur on tomato. Only 7 species of polyphagous owlet moths (Noctuidae) (23 individuals) are known as pests of tomato. Thus, the highest proportion of species and individuals was occupied by specialized species that cannot damage Solanaceae. Potentially damaging species occupied the lowest proportion (Tabs III–VII, Fig. 5).



4: *Numbers of species and individuals of moths registered in each sampling date*



5: *Proportion of captured moths in categories according to feeding requirements; see Sampling methods*

III: *Captured saprophagous moths (Sa)*

Taxon	Number
Tineidae	
Morophaga choragella (Den. & Schiff.)	1
Oecophoridae	
Promalactis procerella (Den. & Schiff.)	1
Pyralidae	
Hypsopygia costalis (Fabricius)	78
Hypsopygia glaucinalis (Linnaeus)	1
Pyralis farinalis (Linnaeus)	3
Geometridae	
Idaea aversata (Linnaeus)	1
Idaea dimidiata (Hufnagel)	3
Idaea fuscovenosa (Goeze)	2
Idaea humiliata (Hufnagel)	1
Idaea serpentata (Hufnagel)	1
Erebidae	
Herminia tarsicrinalis (Knoch)	1
Polypogon tentacularia (Linnaeus)	6

IV: *Captured trophic specialists that cannot develop on Solanaceae (Sp)*

Taxon	Number
Yponomeutidae	
Argyresthia spinosella Stainton	2
Yponomeuta malinellus Zeller	1
Plutellidae	
Plutella xylostella (Linnaeus)	487
Pterophoridae	
Cnaemidophorus rhododactyla (Den. & Schiff.)	2
Emmelina monodactyla (Linnaeus)	5
Tortricidae	
Acleris bergmanniana (Linnaeus)	5
Agapeta hamana (Linnaeus)	3
Bactra lancealana (Hübner)	2
Celypha rufana (Scopoli)	9
Cydia pomonella (Linnaeus)	1
Dichrorampha acuminatana (Lienig & Zeller)	6
Endothenia nigricostana (Haworth)	1
Eucosma cana (Haworth)	1

IV: *Continuation*

Taxon	Number
Hedya nubiferana (Haworth)	8
Hedya pruniana (Hübner)	1
Notocelia uddmaniana (Linnaeus)	2
Tortrix viridana (Linnaeus)	2
Coleophoridae	
Coleophora argentula (Stephens)	1
Gelechiidae	
Acompsia cinerella (Clerck)	3
Brachmia dimidiella (Den. & Schiff.)	1
Dichomeris limosellus (Schläger)	1
Helcystogramma albinervis (Gerasimov)	1
Helcystogramma rufescens (Haworth)	5
Scrobipalpa ocellatella (Boyd)	2
Limacodidae	
Apoda limacodes (Hufnagel)	1
Pyralidae	
Homoeosoma sinuella (Fabricius)	2
Oncocera semirubella (Scopoli)	1
Crambidae	
Catoptria falsella (Den. & Schiff.)	1
Crambus lathoniellus (Zincken)	1
Crambus perlella (Linnaeus)	3
Chrysoteuchia culmella (Linnaeus)	3
Pyrausta despicata (Scopoli)	5
Platytes cerussella (Den. & Schiff.)	35
Scoparia pyralella (Den. & Schiff.)	2
Geometridae	
Catarhoe cuculata (Hufnagel)	1
Epirrhoe alternata (Müller)	2
Isturgia arenacearia (Den. & Schiff.)	1
Ligdia adustata (Den. & Schiff.)	1
Timandra comae Schmidt	1
Erebidae	
Rivula sericealis (Scopoli)	4
Noctuidae	
Deltote bankiana (Fabricius)	2
Acontia trabealis (Scopoli)	3
Oligia latruncula (Den. & Schiff.)	1
Oligia strigilis (Linnaeus)	1
Oligia versicolor (Borkhausen)	1

V: *Captured polyphagous moths not known on Solanaceae (unlikely harmful)*

Taxon	Number
Tortricidae	
Adoxophyes orana (Fischer v. R.)	2
Agapeta zoegana (Linnaeus)	1
Celypha striana (Den. & Schiff.)	1
Eana canescana (Guenée)	9
Pandemis heparana (Den. & Schiff.)	2
Spilonota ocellana (Den. & Schiff.)	2
Crambidae	
Ostrinia nubilalis (Hübner)	2
Geometridae	
Chlorissa cloraria (Hübner)	1

VI: *Captured polyphagous moths that can develop on tomato*

Species	Number
Tortricidae	
Archips podana (Scopoli)	2
Celypha cespitana (Hübner)	4
Celypha lacunana (Den. & Schiff.)	5
Celypha rivulana (Scopoli)	10
Cnephasia pumicana (Zeller)	5
Eana incanana (Stephens)	21
Endothenia quadrimaculana (Haworth)	2
Pandemis dumetana (Treitschke)	5
Zelotherses paleana (Hübner)	1
Pyralidae	
Nyctegretis lineana (Scopoli)	1
Geometridae	
Colostygia pectinataria (Knoch)	1
Peribatodes rhomboidaria (Den. & Schiff.)	2
Scopula immorata (Linnaeus)	8
Scopula virgulata (Den. & Schiff.)	2

VII: *Captured polyphagous owlet moths (Noctuidae) that can damage tomato (Po++); Czech species names are also given for practical reasons*

Taxon	Number
Agrotis exclamationis (Linnaeus) (osenice vykřičníková)	7
Celypha segetum (Den. & Schiff.) (osenice polní)	1
Anarta trifolii (Hufnagel) (můra jetelová)	1
Hoplodrina ambigua (Den. & Schiff.) (blýskavka jitrocelová)	11
Ochropleura plecta (Linnaeus) (osenice čekanková)	1
Xestia c-nigrum (Linnaeus) (osenice černé c)	1
Xestia xanthographa (Den. & Schiff.) (osenice žlutoskvrnná)	1

DISCUSSION

The authors are not aware of any publication dealing with similar issues. The focus in greenhouses is on a few key pests that have been studied from a variety of perspectives and about which, in turn, much has been published; *Tuta absoluta* and *Chrysodeixis chalcites* in tomato crops (see also Introduction), *Plutella xylostella* (Linnaeus, 1758) in cruciferous vegetables, *Duponchelia fovealis* Zeller, 1847 in ornamental greenhouse plants and several species of the genus *Elophila*, mostly of South-East Asian origin, in aquatic plant greenhouses. But this is a different issue than we have dealt with, and it is unnecessary to cite specific publications here. Therefore, in the following discussion, we can evaluate or try to justify only our own results. The biological control of some pests carried out in the greenhouse was not aimed at moths and could not in any way influence the results presented and discussed here.

It is clear from the results that the species spectrum of moths found in the greenhouse reflects the nature of the fauna and habitats in the immediate vicinity of it. The registered species are widely distributed in agricultural, or in the open landscape in general, and in residential environments. Adult moths enter the greenhouse partly at random, and are undoubtedly attracted to a greater extent by the internal lighting (high pressure sodium lamps with a dominant wavelength of 598 nm). *Plutella xylostella* was a significantly dominant species with more than 58% of the total number of individuals. Individuals of this species were clearly attracted by light, assuming their mass occurrence in the vicinity of the greenhouse (capturing current migration, abundance in the year of the study, or an over-breeding in the vicinity). Similarly, the relatively high number of species and individuals of some grassland-associated species of Crambidae and Tortricidae reflect the nature of the surrounding habitats and their occurrence in the greenhouse is purely coincidental. The greater abundance of species and individuals of owlet moths (Noctuidae) reflects the affinity of most species of this family for light sources. The somewhat higher number of saprophagous species (14% of species and 12% of individuals, compared to about 4% in the central European fauna) indicates that these species can develop at least in the short term on the growing medium and other organic residues in the greenhouse without any negative effects, but may equally reflect the food supply in the immediate vicinity of the greenhouse.

As many as 92% of species and 97% of individuals show no food or other relationship to the tomato crop and their occurrence in the greenhouse is coincidental. The clearly higher number of species and individuals captured in June compared to October and November again demonstrates the relationship of the captured species to the external environment, i.e. reflecting the peak period of activity and abundance of most insect species in central European conditions. The rate of the occurrence constancy of individual species is primarily influenced by their seasonal dynamics. Species with higher constancy (species captured in both June and autumn samplings) develop more generations annually or show a temporally extended period of adult occurrence up to the autumn months. No species were recorded in the autumn months that were no longer present in external conditions at that time (the detection of such species would indicate the development of subsequent generations and longer survival in the indoor greenhouse environment independent of the external environment). Only the considerably high number of *Hypsopygia costalis* individuals indicates a very likely permanent presence in the greenhouse and its development on organic residues without any negative effects.

The higher number of captured species and individuals in the part of the greenhouse with the culture restoration during the study was against logical expectations. It could only have been due to the fact that the large entrance gate (3 × 2.5 m) in this part of the greenhouse was open more often during the harvest and the ongoing research in June, through which moths could fly in. The significant differences in species composition in the two parts of the greenhouse with only 30% species similarity may indicate the short-term nature of the research, but also the randomness with which species enter the greenhouse from the outside environment. As the length of the survey increases, one would expect a gradual increase in species similarity between the two parts until the “species potential” around the greenhouse is exhausted. The distance between the traps was very small due to the mobility of

moths and the differences in numbers of species and individuals captured between the traps were probably due to mere chance.

The very low number of polyphagous species that could damage the tomato, and the particularly low number of their individuals, indicates that even these species were not attracted by the food supply and entered the greenhouse by chance without giving rise to the next generation.

CONCLUSION

All the moth species detected are highly likely to have entered the greenhouse from the external environment and in the vast majority have no feeding relationship with the tomato culture. Of the 87 species found, only 7 polyphagous owlet moth species (Noctuidae) can be considered as pests of tomato. Given the system of greenhouse operation, the existence of a permanent population of these species is unlikely. Only the caterpillars of the next generation may cause short-term, one-off damage, depending on the number of females that have entered the greenhouse and laid tomato plants. None of the non-indigenous species introduced with the seedlings have been recorded as having the potential to cause significant subsequent damage.

Acknowledgements

The authors would like to thank the employees of the Farm Kameničany, Slovakia, namely Mgr. Zuzana Zapotocká, Ph.D. and Radek Fojtík for enabling research and cooperation.

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