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An overview of alien, invasive Microlepidoptera species, potential pests in agri- horti- or silviculture, recently found in Hungary

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REVIEW

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ABSTRACT

Along with climate change, or by transportation of agricultural products, such as fruits and ornamental plants, their alien insect pests have also started to appear in Hungary. Although these pest species are sometimes sparsely studied, their biology and interactions with their host plants provide key information for monitoring their spread and identifying their vulnerable points, targets for developing methods preventing their overpopulation. In this review article we have collected data on newly emerged moth species recently found in Hungary that might threaten plantations in Hungary in the near future.

KEYWORDS

alien pest, moth, monitoring, unknown sex pheromone composition, chemical ecology

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INTRODUCTION

Central Europe, particularly Hungary, is experiencing an increase in new species introduced by global trade or spreading from the Mediterranean in response to climate change. Invertebrates are spreading most often with plant materials like woody parts, plant propagula, or in soil. Many of these organisms are considered as pests especially, if they feed on agricultural crops. This article will discuss eight Microlepidoptera species that have been recently discovered in Hungary, or that have possibly switched quite recently from their native host plants to ornamental or horticultural hosts. Criteria for the selection of moth species were their quite recent detection in Hungary, the hidden lifestyle of their larvae and their host plant, which were quite free from economically important moth species before. Typically, these species dealt in this overview were unimportant and therefore scarcely studied within their original range of occurrence. Therefore, only limited knowledge was available on their biology at the time they appeared in new areas, in our case to Hungary. However, as soon as they colonize a new region or switch to new host plants of economic significance, their behaviour needs to be studied in order to establish basis for new control methods. This overview is intended to summarise most important recent basic knowledge on the selected invasive moth species.

BRIEF ACCOUNT OF THE SELECTED SPECIES

Cydia interscindana (Möschler, 1866) (Tortricidae)

Hitherto often referred in English as “Juniper piercer”

Cydia interscindana adult (Fig. 1)

Cydia interscindana damage (Fig. 2)

It was first detected in Hungary in 2014, in pheromone traps installed to monitor the populations of the codling moth, *Cydia pomonella* (Linnaeus, 1758) (Szabóky, 2014). *C. interscindana* originally feeds on *Juniperus oxycedrus* (Linnaeus) (Cupressaceae), a native juniper species in the Mediterranean region of Europe (Miller, 1990; Razowski, 2003). Likely, the moth was brought to Hungary with saplings of the host plant. In Hungary it has two generations, adults of the first generation emerge around the middle of May and the flight time lasts till the end of June; the second generation’s flight time starts in August and lasts till September (Takács et al., 2022). The larvae mine in the sapwood of the branches and its frass blocks the nutrients’ transport within. In Hungary the larvae were found to feed on *Cupressus* × *leylandii* A.B. Jacks. & Dallim 1926, *Platycladus orientalis* (L.) and *Chamaecyparis lawsoniana* Parl. 1864 (Cupressaceae). While males were caught in Hungary by pheromone traps targeted codling moth, the composition of female-emitted sex pheromone is unknown. The development of a sensitive and species-specific monitoring system would be highly needed in ornamental tree nurseries, where *C. interscindana* may gain an increasing contribution to the decline of Cupressaceae, already seriously suffering from the cypress bark beetle, *Phloeosinus aubei* Perris, 1855 (Coleoptera: Curculionidae, Scolytinae) and the cypress jewel beetle, *Lamprodila festiva* (Linnaeus, 1767) (Buprestidae).

Fig. 1. Cydia interscindana adult (photo: Anna Teski)

Fig. 2. Cydia interscindana damage (photo: Anna Teski)

Cydia pactolana (Zeller, 1840) (Tortricidae)

Hitherto often referred in English as "Scarce spruce piercer or Spruce bark tortrix"

Cydia pactolana is an upcoming, univoltine pest of spruce, larch and pine plantations. Locally it can seriously affect plantations, in case moth population is large enough especially when trees are young and weakened by drought (Szabóky and Csóka, 2010; Tuba and Kelemen, 2015). The larvae bore under the tree bark into the phloem causing the death of branches or the entire tree. Uimari et al. (2018) tested, whether the occurrence of *C. pactolana* and the appearance of pathogenic fungus *Neonectria fuckeliana* (C. Booth) Castl. & Rossman; which recently became a serious threat to Norway Spruce forests, has a correlation with each other. Nevertheless, they could not prove in which order the pest and pathogen colonizes the spruce trees. It seems that *N. fuckeliana* infests secondarily on spruce branches and trees, when *C. pactolana* damage occurs.

Cydia pactolana males were reported to be attracted to (Z)8-dodecenol (Z8-12OH); this seems to be in a concentration dependent manner, with higher captures at the 500 µg dose, than to the 1,000 µg dose (Booij et al., 1986). They used both delta- and funnel traps in six heavily infested plots of conifers in the Netherlands: spruce, pine and larch. The traps were baited with various combinations of 500 µg Z8-12OH, (E)8-dodecenol (E8-12OH), Dodecenol (12OH), (Z)-8-dodecenyl acetate (Z8-12Ac) and a double dose of Z8-12OH. The combination of Z8-12OH and Z8-12Ac and the double dose of Z8-12OH caught significantly less males, than the other traps. Z8-12Ac seems to be an inhibitor to this species. However, according to some recent, uncertified growers' claim from West-Hungary the monitoring traps did not perform as well as expected. Why, if so, the possible reasons for that remained unclear, nevertheless investigation of the pheromone composition of the population in concern might be useful. Olenici et al. (2007) surveyed non-target lepidopteran species with pheromone traps of various tortricid species. In their trapping studies they included sites of conifer seed orchards and mature tree stands as well. During 1989 and 1990 the pheromone trap of *Gravitarmata margarotana* (Heinemann, 1863) caught several specimens of *C. pactolana*. This pheromone capsule contained Z9-12Ac, E11-14Ac, Z11-14Ac, 12Ac, 14Ac in a 5:2:3:3:1 ratio. However, Witzgall et al. (1996) in a similar field trapping experiment found *C. pactolana* specimens in traps baited with E8E10-12Ac and E8Z10-12Ac in 1:1 ratio.

Clepsis dumicolana (Zeller, 1847) (Tortricidae)

English name not found

Although common ivy (*Hedera helix* L.) is considered invasive in many natural environments, varieties are still marketed as an ornamental creeping shrub, used as a ground or wall cover. *C. dumicolana* larvae can cause severe damage on the foliage, which represents the ornamental value of the plant. Infested plants are not marketable, and those kept in gardens lose their aesthetic value. Recently this tortrix species, which also originates from the Mediterranean, started to spread towards the northern regions of Europe (De Prins et al., 2008). The female lays her eggs on the ivy leaves. Early instar larvae feed on the upper side of the leaf, peel the external tissue layers while older ones perforate the leaves. They pupate between leaves, spun together. In Belgium and Germany this species has two generations; unlike in the Mediterranean region, where there is only one. It is supposed that the hot and dry Mediterranean summer humpers the development of further generations, while the Atlantic climate favours the development of further generations. In Hungary, the first's flight last from May to July, the second generation is on the wings from August till September, in warmer weather even till October (Fazekas, 2020). They overwinter as larvae. The adults can be seen flying near their food plant or sitting on the leaves, it is unclear in what time are they active for mating. Occasionally the caterpillars can cause large foliage losses especially on the shoot apices. This species' chemical ecology is yet to be studied, but Frerot et al. (1979) caught a few males with field traps baited with the mixture of (Z)-11-tetradecen-1-ol acetate and (E)-11-tetradecen-1-ol acetate.

Choreutis nemorana (Hübner, 1799) (Choreutidae)

English name: fig-leaf skeletonizer

Choreutis nemorana adult (Fig. 3)

Choreutis nemorana (synonyms: *Simaethis nemorana* and *Anthophila nemorana*), is a member of the Choreutidae, which family was previously represented in Hungary only by eight species (Fazekas, 2015). It is a species that came to Central Europe from the southern regions of the continent, lately the moth slowly spreading towards Central and Northern Europe. Whether by anthropogenic effects, or because its hostplant has been able to overwinter in colder climate, the moth has adapted its lifecycle to continental winters. The adult wingspan is around 15–20 mm, the basic color of the forewings varies from reddish brown to ocher brown, with whitish markings. The hindwings are brownish, with two pale brown dots on the edge. The larvae feed on leaf tissues of fig leaves (*Ficus carica* L.), leaving only the veins of the leaf and spinning a silk web over it for protection. Once they are ready to pupate they roll up the side of an intact leaf or create the cocoon on a branch. The adults of the first generation are on the wing

Fig. 3. Choreutis nemorana adult (photo: Attila Takács)

from June, in the vicinity of the host plants. The second-generation larvae emerge around the middle of July the imagoes overwinter in sheltered crevices. There are several parasitoids that were recorded to attack *C. nemorana* larvae, Hymenoptera species such as *Itoplectis tunetana* (Schmiedeknecht, 1914) (Ichneumonidae), *Dolichogenidea candidata* (Haliday, 1834) (Braconidae) (Kavallieratos et al., 2019); *Stenomesius rufescens* (Retzius, 1783) (Eulophidae) (Fazekas, 2019) and *Elodia atricans* (Herting, 1975) (Diptera, Tachinidae) (Kara et al., 2003).

Its pheromone is unknown.

Coptodisca lucifluella (Clemens, 1860) and *C. juglandiella* (Chambers, 1874) (Heliozelidae)

Referred in English as black walnut leafminer and bitternut hickory leafminer, respectively

Coptodisca lucifluella adult (Fig. 4)

Cydia juglandiella adult (Fig. 5)

These are newly introduced leaf miners from the Heliozelidae family that live on various species of Juglandaceae. They originate from the Nearctic region; in Europe first appeared in walnut orchards in Northern Italy around 2010 (Bernardo et al., 2011). The adults of these species are morphologically very similar, making differentiation between *C. lucifluella* and *C. juglandiella* very difficult, thus the lifecycle, host plants and mine shape are the basis for identification (Takács et al., 2020). *C. juglandiella* and *C. lucifluella* have a dark toned silver-grey body, and light silver-grey head; each species' forewing has a silver basal half with two black rimmed white triangular patch. The difference between the species is that *C. juglandiella* forewing has a basal patch of color transitions from silvery grey to the dorsal patch's yellow and the dorsum patch is narrow; while the forewing's area of *C. lucifluella* has a color between silvery grey color of the basal patch and the color of the tornal patch, which is dark fuscous. *C. juglandiella* larvae are known to feed on black walnut, *Juglans nigra* L., while *C. lucifluella* feeds on common walnut, *J. regia* L. and on pignut hickory, *Carya glabra* (Mill.) Sweet,

Fig. 4. Coptodisca lucifluella adult (photo: Attila Takács)

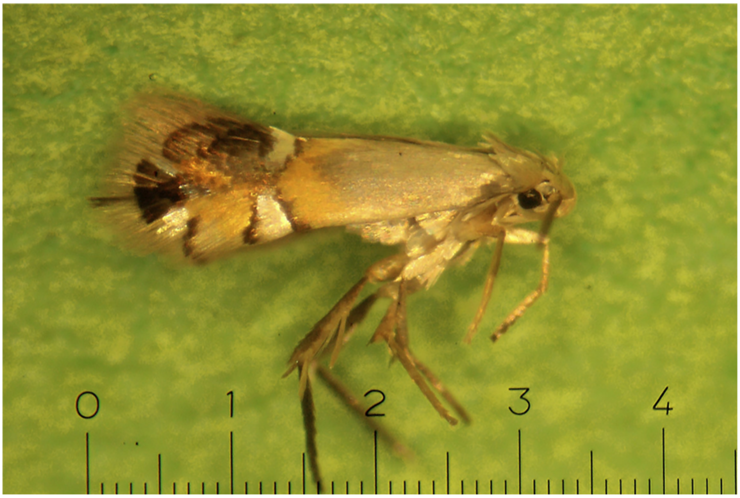

Fig. 5. Coptodisca juglandiella adult (photo: Attila Takács)

1826 (Bernardo et al., 2015). Takács et al. (2020) in Hungary collected and reported specimens of *C. juglandiella* from butternut (white walnut), *Juglans cinerea* L., and from Caucasian wingnut *Pterocarya fraxinifolia* (Poir.) Spach, 1834 both found to be a new host plant of this species. Furthermore, Arizona walnut, *Juglans major* (Torr.) A. Heller, 1904 and bitternut hickory, *Carya cordiformis* (Wangenh.) K. Koch were also reported by Takács et al. (2020).

The females lays the eggs on the underside of the host plant leaves (Bernardo et al., 2011). The newly hatched larvae feed on the mesophyll tissue *C. juglandiella* creates a circular mine and hides its frass under a parenchyma shield; *C. lucifluella* mines are more angular and elongated, frass is dispersed in the mine (Takács et al., 2020). Once fully developed, they create a flat case to pupate, in the last generation for the prepupal stage to overwinter.

Gualtieri et al. (2015), researching the parasitoid composition of *C. lucifluella* in Italy, reared specimens of species of several parasitoid genera: *Chrysocharis* spp., *Neochrysocharis* sp. and *Pnigalio soemius* complex (Hymenoptera: Eulophidae). These species are native in Europe, but in one case they find a specimen native to the Nearctic region, *Cirrospilus coptodiscae* (Girault, 1916). The authors hypothesize that this species followed *C. lucifluella* to Europe. Mustățea and Chireceanu (2023) collected *J. regia* leaves with mines of *C. lucifluella* in Romania on two localities: Northern Bucharest and Moara Domnească. They discovered a high percentage of parasitism among the collected mines: 17.4% and 31.8% of the samples from Northern Bucharest and Moara Domnească respectively. The emerged parasitoid speciess thus far had not been identified.

To our knowledge the chemical ecology of *C. lucifluella* and *C. juglandiella* is unknown.

Phyllochnistis vitegenella (Clemens, 1859) (Gracillariidae)

English name not found

Phyllochnistis vitegenella mine (Fig. 6)

Fig. 6. Phyllochnistis vitegenella mine (photo: Attila Takács)

This species is a member of the species-rich Gracillariidae family and is native to North America. In Europe, it appeared on grape (*Vitis vinifera* L.) in wineyards of Northern Italy in 1995 (Posenato et al., 1997), from there it spread toward Central and Western Europe. In 2014, *P. vitegenella* was discovered for the first time in Hungary (Szabóky and Takács, 2014). Two flights were recorded in Hungary, the second overwinters as adults (Bodor, 2014). The adults have a 5.5–6.5 mm of wingspan.

After its first emergence in Italy, Marchesini et al. (2000) conducted a survey regarding the indigenous parasitoid species that were reared from *P. vitegenella* larvae. The identified species were Hymenopteran wasps of the family Eulophidae *Closterocerus trifasciatus* Westwood, 1833, *Cirrospilus vittatus* Walker, 1838, *Cirrospilus diallus* Walker, 1838, *Cirrospilus lyncus* Walker, 1838, *Chrysocharis nephereus* (Walker, 1839), *Chrysocharis pentheus* (Walker, 1839), *Chrysocharis* sp., *Minotetrastichus ecus* (Walker, 1839) and *Euderus* sp. The highest parasitization rate was found in the 4th generation, where it reached 51% of all *P. vittegenela* specimens collected.

The pheromone of *P. vitegenella* is unknown, but in a field monitoring test in South Florida Kawahara et al. (2013) among several other species caught several *P. vitegenella* males with traps baited with the 3:1 blend of (Z,Z,E)-7,11,13-hexadecatrienal and (Z,Z)-7,11-hexadecadienal, a blend that is used to attract *P. citrella,* a related species. However, no unbaited control traps were used and captured *P. vitegenella* specimens were identified as morphotypes. Therefore, corroboration of these results would be useful, such as chemical identification of the female produced sex pheromone.

Phyllonorycter millierella (Staudinger, 1871) (Gracillariidae)

Referred in English as nettle-tree leaf miner by Jurc et al. (2016). Broadly accepted English name not found

Phyllonorycter millierella adult (Fig. 7)

In 2016, Takács et al., found specimens of a Gracillarid leafminer species, new to Hungary. It was determined as *P. millierella,* which originates from the Mediterranean area. Larvae create grey, tentiform mines on the underside of the leaves of European nettle tree (*Celtis australis* L.) and that of the Caucasian nettle tree (*Celtis caucasica* Willd, 1806), starting from the junction of the veins. The mines are at first not visible from the upper side. As the larva grows the leaf starts to deform creating the tent, eventually the upper side of the mine turns grey as well (Kuznetzov and Baryshnikova, 2006). The larva pupates in a cocoon spun in the middle of the mine. Adult moths' wingspan is 7–8 mm, the forewings are yellowish with four white stripes running diagonally from the basal part to the tip of the wing. It has two generations per year. The first generation are on wings from May to June; the second one emerge from August to October.

There were no research regarding the chemical ecology of *P. millierella*, its pheromone is unknown.

Key information of the selected species are summarized in Table 1.

OUTLOOK: POSSIBILITIES OF MONITORING AND CONTROL MEASURES

Aside from grape every other of the affected host plants are either ornamentals, or such fruit trees, which are considered special cultures of limited growing areas. There are only very few chemical pesticides which can be applied in such small cultures, partially because of recent banning several ones. Therefore, other control measures should be developed for an effective

Fig. 7. Phyllonorycter millierella adult (photo: Attila Takács)

Table 1. Key information on the newly established populations of the selected species in Hungary, as well as so far data on their chemical ecology (composition of possible sex attractants)

			First detection in Hungary			Chemical Ecology		
Species	Family	Original distribution	Year and site of first detection in Hungary	Reference	No. of flights in Hungary	Compound	Reference	Remarks
Cydia interscindana (Möschler, 1866)	Tortricidae	Mediterranean region	2014, Budapest	Szabóky (2014)	2	E,E-8,10-12OH	Szabóky (2014)	Attractant only. Pheromone not known
Cydia pactolana (Zeller, 1840)	Tortricidae	Spruce and lurch stands of the Alpes and N-European regions	1986, Mátra	Szabóky (1986)	1	Z8-12OH E8E10-12Ac, E8Z10-12Ac Z9-12Ac, E11-14Ac, Z11-14Ac, 12Ac, 14Ac	Booij et al. (1986) Witzgall et al. (1996) Olenici et al. (2007)	Attractants only. Conflicting published results. Pheromone not known.
Clepsis dumicolana (Zeller, 1847)	Tortricidae	Mediterranean region	2020, Budapest, Pécs	Fazekas (2020)	2	Z11-14Ac, E11-14Ac	Frerot et al. (1979)	Sporadic captures only. Pheromone not known.
Choreutis nemorana (Hübner 1799)	Choreutidae	Mediterranean region	2011	(2007)	2	–	–	Pheromone not known.
Coptodisca lucifluella (Clemens, 1861)	Heliozelidae	Nearctic	2017	Takács et al. (2017)	3	–	–	Pheromone not known.

(continued)

Table 1. Continued

			First detection in Hungary			Chemical Ecology		
Species	Family	Original distribution	Year and site of first detection in Hungary	Reference	No. of flights in Hungary	Compound	Reference	Remarks
Coptodisca juglandiella (Chambers, 1874)	Heliozelidae	Nearctic	2022	Takács et al. (2020)	3	–	–	Pheromone not known.
Phyllocnistis vitegenella Clemens, 1859	Gracillariidae	Nearctic	2014, Budapest	Szabóky and Takács (2014)	2	Z,Z,E-7,11,13-16Ald: Z,Z-7,11-16Ald (3:1)	Kawahara et al. (2013)	Side captures. Pheromone not known.
Phyllonorycter millierella (Staudinger, 1871)	Gracillariidae	Mediterranean region	2016, Enying	Takács et al. (2016)	2	–	–	Pheromone not known.

integrated pest management system. Unfortunately, right now only hardly any specific methods are available, just a few general precaution techniques can be recommended.

Agrotechnical prevention

Agro-technical preventions, for example, include among others choosing resistant varieties, or covering the crop with protective net from insect pests (Keszthelyi, 2017). As for protective nets, it is highly unlikely that such ones could be used under open-air conditions, because of technical and economic constrains. Furthermore, little if anything is published about resistant/tolerant cultivars in respect of these pests newly arrived to Hungary. More rigorous literature surveys should be directed to possible publications, not referred in common international databases, reporting investigations in that direction, in respective regions of the original distribution areas as these pests.

What remains for todays is physical protection e.g.: removing the infected parts of the plant, when feasible (time- and hand power consuming process).

Parasitoids

Biological plant protection methods are nowadays in focus of general attention for developing new control measures, and indeed, introduction of parasitoids, which regulate populations of the pests within their native area of occurrence can be useful tools.

A good example to such control attempts is the chestnut gall wasp (*Dryocosmus kuriphilus* Yasumatsu, 1951) (Cynipidae) native to China. It became an invasive pest of chestnut species first in Japan then it spread to North America and Europe (Payne et al., 1983; Brussino et al., 2002). Several attempts were made to stop or prevent its invasion, but the most successful method seemed to be the use of parasitoid wasps. Huang et al. (1988) identified several of its natural enemies in China. The species that infested the highest number of gall wasp larvae was *Torymus sinensis* Kamijo, 1982 (Torymidae) eventually became commercially available and introduced to Japan, Europe and America (Rieske, 2014). Genetical tests later indicated that it is unlikely that *T. sinensis* would hibridize with local *Torymus* species either in Japan or in Europe. This study also reported on the affinity of *T. sinensis* to parasitize the native gall wasp species. However, the exact same study also points out, that *T. sinensis* may represent an invasive threat to local gall wasp populations (Gil-Tapetado et al., 2023). Experiments assessing native parasitoid wasp populations of Italy after the introduction of *T. sinensis* showed their ability to infest *D. kuriphilus* being very limited, as about only 2% of gall wasps were parasitized by native parasitoids (Quacchia et al., 2013).

While detailed risk assessments of such a planned introduction to the ecosystems in the concerned areas have to be preceded, the starting point of such research projects are certainly revealing the parasitoid fauna in the native areas (Zhi-yong, 2009). There are also several studies regarding parasitoids that are indigenous to the areas newly invaded by a pest (Aebi et al., 2007). Nevertheless, a success story was, upon careful preceding studies, the introduction of *T. sinensis* as a biocontrol agent against the sweet chestnut gall wasp *D. kuriphilus* (Matošević et al., 2015; Avtzis et al., 2019; Kos et al., 2021).

The identified parasitoid species that were reared from the respective hosts dealt in this review are listed above, at the subheadings of the respective pest species. However, their populations may not be sufficient to keep the new pest's spread under control. As for commercially available parasitoid species, they can, of course, not be used against alien pests in most cases because the parasitoid-host relationship is rather specific. Especially rare to find the proper parasitoid against a pest which develop in the hard phloem of the host trees. To our knowledge for those species discussed in this review no such parasitoids have been reported yet, which could be directly used in practice, as effective biological control agents. Currently there is a limited assortment of parasitoid invertebrates available to farmers, that would be compatible with the invasive pests, which threaten their crops (biobest.com; biocontmagyarorszag.hu).

Botanical pesticides

Several plant-derived insecticides are commercially available and used and even more are being researched world-wide (Tavares et al., 2021). There are several studies which report testing plant extracts as means of pest control agents against lepidopterous larvae. The most popular plant extracts are as follows, the neem tree (*Azadiracta indica* A. Juss) (Shapiro et al., 1994; Bruce et al., 2004), tobacco plant (*Nicotiana tabacum* L.) (Amoabeng et al., 2013; Andjani et al., 2019), and marigold (*Tagetes erecta* L.) (Salinas-Sánchez et al., 2012; Mishra et al., 2023). However, measuring the effectiveness of these extracts is difficult. Not only the targeted insect species may react differently to the same kind of extract, but one has to face to the problem of how to produce extracts of standard quality. As for the sensitivity of pests, this depends for example on in which life stages is the population at the time of treatments. As for producing standard extracts, the set of compounds extracted during the process and the compounds' ratio can be greatly dependent on several factors during the collection process (Puripattanavong et al., 2013). Comparing the published data on these extracts is also problematic, as researchers use different tests and measuring methods to determine a plant-derived insecticide's effectiveness.

However botanical pesticides have successfully been developed to control several other pest species. Therefore plant-derived extracts should be studied as potential biological control methods also against the pests covered by this review.

Semiochemicals- sex pheromones

Semiochemicals, particularly sex pheromones are, in general, widely used for detecting, monitoring, and in some cases even for controlling pest populations.

Examples include many pest species belonging to Microlepidoptera, first of all codling moth (Witzgall et al., 2010). These methods are based on the knowledge of pheromonal communication of the pest. However, this knowledge is either completely missing in case of the species covered by this review or, when sporadic information is available, these are incomplete, or questionable. Therefore, the investigation, or re-investigation of the pheromone composition of the above-mentioned pests would be highly desirable. For this purpose, we initiated some studies, with the hope that in due time pheromone traps could be developed for these pests, as well, or at least for some of them.

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