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ORIGINAL PAPER

The distribution of *Obolodiplosis robiniae* on black locust in Slovakia

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Abstract For the first time during October 2006, the occurrence of *Obolodiplosis robiniae* (Haldeman 1847) (Diptera: Cecidomyiidae) was recorded on the black locust (*Robinia pseudoacacia* L.) in Slovakia. During 2007, field surveys were undertaken to determine the distribution of the species and the infestation ratio at different locations. One year after its first discovery, *O. robiniae* was found throughout southern Slovakia. The gall midge was observed in 148 out of 161 checked locations. The infestation ratio of single leaves varied from 4 to 100%. The infestation ratio of the black locust tree was evaluated during May–June, July–August, and September–October, and accounted for 15–39, 9–53, and 6–49%, respectively. The most frequent infestation ratio fluctuated from 10 to 30% (115 locations). The highest infestation was recorded during July–August. Greater infestation was prevalent in the larger settlements than it was in the countryside. The gall midge was also recorded on *R. viscosa* Vent. Although the results show that *O. robiniae* is nowadays an usual insect with high potential to become an important pest of ornamental black locust or biological control agent against weedy black locust in southern Slovakia, the species do not appear to have reached pest status until now.

Keywords Cecidomyiidae · Gall midge · Infestation ratio · Invasive species · *Robinia pseudoacacia*

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Introduction

The gall midge, *Obolodiplosis robiniae* (Haldeman 1847) (Diptera: Cecidomyiidae), is a Nearctic pest, recently introduced into Europe. The host plant of the species is the black locust, *Robinia pseudoacacia* L. (e.g., Uechi et al. 2005; Csoka 2006; Sheppard et al. 2006; Yang et al. 2006) and *R. viscosa* Vent. (Fabaceae) (Skuhravá et al. 2007). *O. robiniae* has spread during the last 6 years in Europe (Skuhravá et al. 2007) and Asia (Japan, Korea, and China) (Woo et al. 2003; Gagné 2004; Sato and Yukawa 2006; Yang et al. 2006). It was first observed in Europe in Italy during 2003 (Navone and Tavella 2004), and subsequently in the Czech Republic (Skuhravá and Skuhravý 2005; Šefrova and Laštuvka, 2005) and Slovenia (Duso et al. 2005) in 2004. In 2006 the gall midge was observed for the first time in Croatia, Germany (Skuhravá et al. 2007), Hungary (Csoka 2006), Slovakia (Zúbrik et al. 2007), and the Ukraine (Berest and Titar 2007). The presence of *O. robiniae* has been reported recently (in 2007) in the Netherlands (Roskam et al. 2008), Switzerland (Wermelinger and Skuhravá 2007), Austria, France, Poland, Serbia, and the United Kingdom (Skuhravá et al. 2007).

Barnes (1951) summarized the life cycle of *O. robiniae* in North America, while Kodoi et al. (2003), Duso et al. (2005), Skuhravá and Skuhravý (2005), and Skuhravá et al. (2007) in Europe. The species is multivoltine; there are two, three and, in optimal conditions, even four generations per year. These generations may overlap. Adults emerge soon after pupation and the females oviposit on the young leaves, particularly at the terminal parts of the shoots. The first generation occurs from mid-May until the end of June or the beginning of July, the second generation during July and August, and the third during September and October up to mid-November. The larvae pupate in the rolled leaf margins. The larvae of the last generation leave the galls to overwinter and pupate in the soil.

The gregariously feeding larvae cause the margins of the leaflets to thicken and to bend downwards, forming the characteristic leaf margin roll galls (Navone and Tavella 2004; Hoffmann et al. 2007; Wermelinger and Skuhravá 2007). The galls contain 5–6 larvae on average. The galls are green in the beginning; subsequently they turn yellow or pink and may darken and dry up. The galls of different generations can often be found on a single leaflet simultaneously. Whenever high number of larvae infested the newly grown leaflets, they are rolled along the midrib (Skuhravá and Skuhravý 2005; Csoka 2006; Skuhravá et al. 2007). Damage to the leaves depends upon the number of larvae living in the galls (Duso and Skuhravá 2002). Although high infestation can cause serious defoliation (Duso et al. 2005; Sheppard et al. 2006), vigorous trees can compensate for this leaf loss (Duso et al. 2005). Although *O. robiniae* is now widely distributed, infestation levels are low to moderate. Therefore, currently the economic importance of *O. robiniae* seems to be low (Duso and Skuhravá 2002).

In order to know more about the distribution of *O. robiniae* in Slovakia 1 year after its first observation, we analyzed the infestation ratio of the black locust in Slovakia. Since *O. robiniae* is a recent invader, any information is of crucial importance for invasion ecology and to forecast its harmfulness.

Materials and methods

To understand the distribution of *O. robiniae,* the presence of the species was studied at different locations throughout Slovakia during 2007. A total of 161 different locations were surveyed. There were three observation periods, 22 May–29 June, 1 July–15 August, and 29 September–22 October. Only 45 out of all the locations were screened twice (July–August and September–October) in the course of the study. Due to black locust occurrence in southern Slovakia, locations were chosen throughout this part of the country. Most sites were located in the Danube Lowland (southwestern part of Slovakia) and Eastern Slovak Lowland (southeastern part of Slovakia). The westernmost location was Devínska Kobyla (48°11′N, 17°00′E), the easternmost Čierne Pole (48°34′N, 22°05′E), the northernmost Trenčín (48°54′N, 18°02′E), and the southernmost location was Moča (47°46′N, 18°25′E). Altitude ranged from 98 to 315 m a.s.l. within this area. Southwestern Slovakia was investigated more intensively. Locations were defined by a tuft of black locust trees. The sites were situated mainly along roads (47 locations), around and within towns and villages (62 locations) but also in the countryside (52 locations).

For each location a sample of 30 infested leaves was collected and placed into plastic bags. If possible, the infested leaves from one tree were collected at random (no pointing at the leaves with the highest infestation) from the lower twigs up to 2 m height above ground. If there were not enough infested leaves on a tree; we included another tree until the required number of leaves was collected. The procedure was stopped when 30 leaves were collected or after 30 trees were checked. The number of infested leaves and visited trees were noted at each location. The observation period never exceeded 15 min per site. The occurrence of at least one infested leaf per site was considered to be an *O. robiniae* occurrence. On the other hand, the samples/locations less than ten infested leaves were collected during the observation period, and were not considered for the evaluation of the black locust tree infestation.

The collected samples were taken to the laboratory and analyzed. The total number of leaflets and the number of infested leaflets were counted for each leaf in the sample. Based on this data, the infestation ratio for each leaf from each location was estimated as the ratio of infested leaflets to the total number of leaflets. The overall infestation ratio of the black locust trees by *O. robiniae* at each location was estimated as a mean infestation ratio of all leaves in the sample from the location. This procedure provided only crude estimates of the infestation ratio; however, it was considered adequate for the purpose of the survey.

Results

The gall midge was observed at 148 out of 161 locations. *O. robiniae* has invaded a large part of southern Slovakia (Fig. 1). In the south central Slovakia (Banská Bystrica Region) (Fig. 2), occurrence of the species was minimal. The majority of locations without the presence of the species were recorded only in this part of central Slovakia.

South and southwestern Slovakia, where the survey was carried out, belongs to the six out of eight municipal regions of Slovakia. The total number of visited locations varied from 4 to 91 within the municipal regions. Locations without gall midge presence were recorded only in three regions (Banská Bystrica Region, Košice Region, and Trnava Region). The most locations analyzed were in southwestern Slovakia (Nitra Region) (Fig. 2).

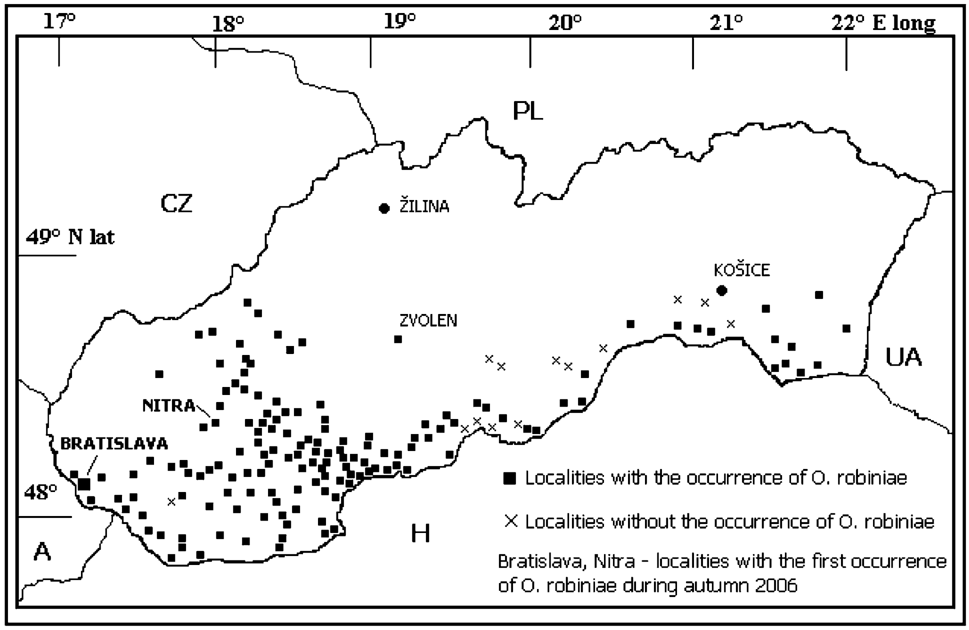

Fig. 1 The occurrence of the gall midge, *Obolodiplosis robiniae* (Diptera: Cecidomyiidae), in Slovakia during 2007

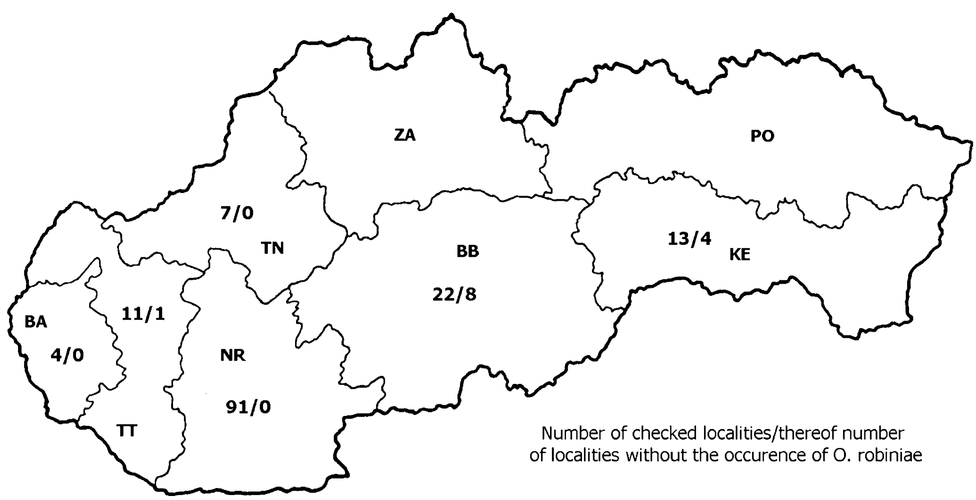

Fig. 2 The occurrence of *Obolodiplosis robiniae* within the different regions of Slovakia during 2007. The map shows the total number of checked locations and thereof the number of locations without presence of the gall midge within the regions. *BA* Bratislava region, *BB* Banská Bystrica region, *KE* Košice region, *NR* Nitra region, *PO* Prešov region, *TN* Trenčín region, *TT* Trnava region, *ZA* Žilina region

Altogether 4,960 leaves of 1,187 black locust trees were evaluated. The infestation ratio of the black locust trees was evaluated at 125 locations, while 23 locations were not considered for evaluation. The infestation ratio of single leaves varied from 4 to 100%, and the overall infestation ratio of the black locust trees ranged from 6 to 52%. There were three locations evaluated during the period of May–June, 109 locations during July–August, and 59 locations during September–October; the infestation ratio of the black locust trees accounted for 15–39, 9–53, and 6–49%, respectively. The most frequent infestation ratio of the black locust trees fluctuated between 10 and 30% throughout Slovakia (115 locations), while an infestation ratio of over 50% was observed only in three locations (during July–August), Nitra, Levice and Sazdice (Table 1). In general, the infestation ratio of black locust trees by *O. robiniae* was higher during the period of July–August, and in the most cases, it declined slightly during September–October. Greater infestation was more obvious within larger settlements (Nitra, Levice, and Šahy) (Table 1) than it was in the countryside (e.g., Sikenica, Tovarníky, and Vyškovce).

The presence of *O. robiniae* was also recorded on *R. viscosa* Vent. at five locations. They were in the Nitra Region, namely Bodza (47°50′N 17°50′E), Číčov (47°46′N 17°46′E), Demandice (48°08′N 18°47′E), Kamenica nad Hronom (47°50′N 18°44′E) and Sokolce (47°51′N 17°50′E).

Discussion

Obolodiplosis robiniae is distributed throughout Europe (Skuhravá et al. 2007). One year after it had been first

Table 1 The infestation ratio of the black locust trees by *Obolodiplosis robiniae* within the different locations checked in Slovakia twice during 2007

Location	Coordinates	Region	Infestation ratio of black locust (%)	
			July–August	September–October
Bátovce	48°18′N 18°45′E	NR	14.8	12.7
Brehov	48°29′N 21°49′E	KE	29.4	22.2
Demandice	48°08′N 18°47′E	NR	32.9	20.0
Domadice	48°11′N 18°47′E	NR	16.9	18.5
Dudince	48°10′N 18°53′E	BB	24.7	9.3
Fil’akovo	48°16′N 19°50′E	BB	12.0	7.8
Hokovce	48°09′N 18°53′E	NR	19.1	9.6
Hontianska Vrbica	48°08′N 18°43′E	NR	25.7	10.3
Ipel’ské Predmostie	48°04′N 19°04′E	BB	26.7	7.2
Ipel’ské Úl’any	48°08′N 19°03′E	NR	9.9	11.6
Ipel’ský Sokolec	48°01′N 18°49′E	NR	45.6	29.9
Kamenica n. Hronom	47°50′N 18°44′E	NR	36.3	18.5
Kubáňovo	48°04′N 18°49′E	NR	27.6	10.7
Kukučínov	48°05′N 18°42′E	NR	31.2	11.2
Levice	48°13′N 18°36′E	NR	51.2	13.1
L’udovítová	48°24′N 18°05′E	NR	26.1	8.8
Moča	47°46′N 18°25′E	NR	15.6	13.2
Nitra	48°19′N 18°05′E	NR	52.7	23.2
Eliášovce	48°07′N 17°28′E	TT	29.2	11.0
Ondrejovce	48°08′N 18°31′E	NR	23.6	14.4
Pastovce	47°58′N 18°46′E	NR	23.1	15.2
Pozba	48°07′N 18°23′E	NR	17.2	13.3
Prašice	48°38′N 18°06′E	NR	34.6	18.3
Príbelce	48°12′N 19°15′E	BB	14.9	15.0
Rastislavice	48°08′N 18°04′E	NR	14.9	12.2
Santovka	48°09′N 18°46′E	NR	22.0	16.0
Sazdice	48°05′N 18°48′E	NR	52.0	18.0
Selice	48°05′N 17°59′E	NR	21.2	14.1
Sikenica	47°56′N 18°41′E	NR	14.7	11.5
Strážne	48°22′N 21°52′E	KE	37.7	12.2
Šahy	48°04′N 18°58′E	NR	36.4	29.1
Šárovce	48°16′N 18°22′E	NR	26.7	7.3
Tekovské Lužany	48°06′N 18°32′E	NR	15.5	11.8
Tekovský Hrádok	48°10′N 18°33′E	NR	24.8	15.1
Tovarníky	48°34′N 18°09′E	NR	13.4	15.5
Tupá	48°07′N 18°54′E	NR	33.3	16.0
Turňa n. Bodvou	48°36′N 20°53′E	KE	12.6	9.3
Vel’ké Chyndice	48°17′N 18°18′E	NR	18.9	16.4
Vinica n. Ipl’om	48°07′N 19°08′E	BB	16.5	14.7
Vinodol	48°02′N 18°02′E	NR	37.7	21.4
Vyškovce n. Ipl’om	48°03′N 18°52′E	NR	15.1	20.7
Zbrojníky	48°07′N 18°42′E	NR	20.4	11.8
Zvolen	48°35′N 19°08′E	BB	12.2	17.8
Želiezovce	48°03′N 18°40′E	NR	21.8	24.7
Žemberovce	48°16′N 18°45′E	NR	20.9	12.1

The observations were based on collection of 30 infested leaves at each location during each observation period

BB Banská Bystrica region, *KE* Košice region, *NR* Nitra Region, *TT* Trnava Region (for orientation see Fig. 2

recorded, the gall midge has invaded a large part of southern Slovakia (Fig. 1). In Slovakia, *O. robiniae* was observed in almost all places where the host plant was grown with the exception of a few locations in central Slovakia (Fig. 1). Because of its rapid spread, we assume that the species had probably been present in Slovakia before October 2006, when we found galls for the first time. Galls are small and hard to detect during the initial stages of infestation, and it is very easy to miss just a few galls distributed in the canopy of a black locust trees when there are very low population densities. The species could have entered Slovakia from the adjacent and already infested countries of the Czech Republic and Hungary. The gall midge was also determined to be on *R. viscosa* in Slovakia. The same host plant was found in Hungary (Skuhravá et al. 2007).

The higher concentration of the host plants may result in a higher probability of interception of the insect arriving in a given location, either by means of transportation or brought by the wind over long distances (Gilbert et al. 2005). The high density of the host plant is also important for *O. robiniae* expansion (Skuhravá et al. 2007). This factor is satisfied in Slovakia, where the black locust is abundant throughout the south (Bertova 1988). Similar to Duso and Skuhravá (2002), the presence of the gall midge in Slovakia was also recorded on the trees of different age, grown in parks, along roads, in hedges or stand margins. Due to high fecundity of females, the exponential growth of the population during the growing season (Skuhravá et al. 2007), continuous sprouting and the leaf growth of the trees (Skuhravá and Skuhravý 2005; Csoka 2006) the species will undoubtedly cover the entire area of black locust occurrence in Slovakia within a few years.

Although many species are able to spread on their own within the newly invaded area, biological invasions also have an anthropogenic origin. Long-distance dispersal is frequently associated with human activities (Gilbert et al. 2005). The role of the motorway network in *O. robiniae* distribution is noted by Skuhravá et al. (2007). Adults of the gall midge or infested leaves with pupae may be transported over large distances on the wheels and other parts of motor vehicles, similarly as it was described in connection with the horse chestnut leaf-miner *Cameraria ohridella* (Deschka and Dimic) (Lepidoptera: Gracillariidae) (e.g., Guichard and Augustin 2002). Successful invasion might require frequent reintroduction up to a density, which guarantees establishment (Gilbert et al. 2005). This idea was also supported by our results. Greater infestation was more obvious within the larger settlements (Nitra, Levice) and the sites situated along the most important transportation highways to previously infested countries (Šahy, Kamenica nad Hronom) than it was in the countryside or farmland, i.e., areas unsuitable for *O. robiniae* distribution, e.g., Sikenica, Tovarníky, and Vyškovce (Table 1). A good example is the southern and rural part of Banská Bystrica Region (Figs. 1, 2), where there are no larger settlements, no highways are present and the country is more mountainous.

Finally, the accidental introduction of infested nursery stock could be another explanation for the spread over long distances as was mentioned for the similar species, e.g., *C. ohridella* (e.g., Augustin and Reynaud 2000).

Yang et al. (2006) recorded infestation rates up to 100% in some provinces of China. This high level of infestation was also reported in the central part of the Czech Republic (Skuhravá et al. 2007). It is difficult to compare the level of black locust infestation between the countries because of unknown methods used for evaluation by the above mentioned authors. One year after the first record of *O. robiniae* in Slovakia, the most frequent infestation ratio of black locust trees ranged between 10 and 30%. Such a low infestation ratio seems to suggest the beginning of the invasion or possibly represents the infestation capacity of the species because of the high mortality due to parasitization (unpublished data). Little is known about *O. robiniae* parasitization in North America but a number of larvae were parasitized in Italy (Buhl and Duso 2008).

The results show that *O. robiniae* is nowadays a common species with high potential to become an important pest of the ornamental black locust or a biological control agent against weedy black locust in southern Slovakia. Although, the species does not appear to have reached pest status yet, pest status may change over time and therefore it is necessary to pay attention to its future occurrence and its possible economic importance.

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