

NATURAL ENEMIES OF DIURAPHIS NOXIA (STERNORRHYNCHA: APHIDIDAE) IN SLOVAKIA

PRIRODZENÍ NEPRIATELIA DIURAPHIS NOXIA (STERNORRHYNCHA: APHIDIDAE) NA SLOVENSKU

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ABSTRACT

A study from 2002 documented the occurrence of natural enemies (parasitoid wasps, predatory flies, entomopathogenic fungi) associated with colonies of the Russian wheat aphid, *Diuraphis noxia* (Kurdjumov, 1913) (Sternorrhyncha: Aphididae), in the spring barley fields in Slovakia. Parasitization by wasps was low (<5.5%) with *Diaeretiella rapae* (McIntosh, 1855) the dominant hymenopterous parasitoid (91% of emerging wasps). The remaining parasitoid guild comprised of *Aphidius ervi* Haliday, 1834 *Aphidius rhopalosiphii* DeStefani, 1902, *Aphidius picipes* (Nees, 1811), *Ephedrus plagiator* (Nees, 1811), *Praon volucre* (Haliday, 1833) (Hymenoptera: Aphidiidae) and two hyperparasites *Asaphes suspensus* (Nees, 1834) (Hymenoptera: Pteromalidae) and *Lygocerus* spp. (Hymenoptera: Ceraphronidae). Predaceous midges (Diptera: Cecidomyiidae) were consistently found with densities ranging from 0.1 to 2.5 larvae per aphid colony. The most abundant predaceous midge was *Aphidoletes aphidimyza* (Rondani, 1847), while *Lestodiplosis* sp. was recorded infrequently. Four syrphids, *Episyrphus balteatus* (De Geer, 1776), *Melanostoma mellinum* (L., 1758), *Sphaerophoria rueppellii* (Wiedemann, 1830), *Sphaerophoria scripta* (L., 1758) (Diptera: Syrphidae) and one pathogenic fungus, *Pandora neoaphidis* (Remaudière et Hennebert) Humber, were recorded.

Keywords: *Aphidoletes aphidimyza*, barley, *Diaeretiella rapae*, dipteran predators, Russian wheat aphid, parasitoids

ABSTRAKT

Výskum, realizovaný v roku 2002 dokumentuje výskyt prirodzených nepriateľov (blanokrídlych parazitoidov, predátorov, entomopatogénnych húb) asociovaných s kolóniami ruskej pšeničnej vošky, *Diuraphis noxia* (Kurdjumov, 1913) (Sternorrhyncha: Aphididae), v porastoch jačmeňa na Slovensku. Parazitácia vošiek bola nízka (<5.5%). Dominantným blanokrídlym parazitoidom bol druh *Diaeretiella rapae* (McIntosh, 1855) (tvoril 91% zo všetkých parazitoidov). K ostatným parazitoidom patrili, *Aphidius ervi* Haliday, 1834 *Aphidius rhopalosiphii* DeStefani, 1902, *Aphidius picipes* (Nees, 1811), *Ephedrus plagiator* (Nees, 1811), *Praon volucre* (Haliday, 1833) (Hymenoptera: Aphidiidae) a dva hyperparazitoidy *Asaphes suspensus* (Nees, 1834) (Hymenoptera: Pteromalidae) a *Lygocerus* spp. (Hymenoptera: Ceraphronidae). Populačná hustota dravých bylomorov (Diptera: Cecidomyiidae) bola konzistentná a pohybovala sa od 0,1 do 2,5 larvy na jednu kolóniu vošiek. Najhojnejším druhom dravého bylomora bol *Aphidoletes aphidimyza* (Rondani, 1847), zatiaľ čo *Lestodiplosis* sp. bol zaznamenaný iba zriedkavo. Spomedzi ďalších prirodzených nepriateľov boli zaznamenané štyri druhy pestríc, *Episyrphus balteatus* (De Geer, 1776), *Melanostoma mellinum* (L., 1758), *Sphaerophoria rueppellii* (Wiedemann, 1830), *Sphaerophoria scripta* (L., 1758) (Diptera: Syrphidae) a jedna entomopatogénna huba, *Pandora neoaphidis* (Remaudière et Hennebert) Humber.

Kľúčové slová: *Aphidoletes aphidimyza*, jačmeň, *Diaeretiella rapae*, dvojkrídle predatory, ruská pšeničná voška, parazitoidy

DETAILNÝ ABSTRAKT

Výskum, realizovaný v roku 2002 dokumentuje výskyt prirodzených nepriateľov (blanokridlych parazitoidov, predátorov, entomopatogénnych húb) asociovaných s kolóniami ruskej pšeničnej vošky, *Diuraphis noxia* (Kurdjumov, 1913) (Sternorrhyncha: Aphididae), v porastoch jačmeňa na Slovensku. Pozorovania sa realizovali na troch lokalitách juhozápadného Slovenska, Maňa, Nevidzany a Tehla. V každom termíne sa pozdĺž okrajov polí hodnotilo 30 náhodných listov jačmeňa s kolóniami *D. noxia*. Napriek tomu, že v 7 až 70% kolónií *D. noxia* boli zaznamenané blanokridle parazitoidy, parazitácia vošiek bola nízka (<5.5%). Dominantným blanokridlym parazitoidom bol druh *Diaeretiella rapae* (McIntosh, 1855) (tvoril 91% zo všetkých parazitoidov). K ostatným parazitoidom patrili, *Aphidius ervi* Haliday, 1834 *Aphidius rhopalosiphii* DeStefani, 1902, *Aphidius picipes* (Nees, 1811), *Ephedrus plagiator* (Nees, 1811), *Praon volucre* (Haliday, 1833) (Hymenoptera: Aphidiidae) a dva hyperparazitoidy *Asaphes suspensus* (Nees, 1834) (Hymenoptera: Pteromalidae) a *Lygocerus* spp. (Hymenoptera: Ceraphronidae). Všetky druhy parazitoidov neboli doteraz ako parazitoidy *D. noxia* na Slovensku zaznamenané. Príčinou nízkej parazitácie v kolóniách je pravdepodobne pravidelný výskyt dravých bylomorov. Populačná hustota dravých bylomorov (Diptera: Cecidomyiidae) bola konzistentná a pohybovala sa od 0,1 do 2,5 larvy na jednu kolóniu vošiek. Najhojnejším druhom dravého bylomora bol *Aphidoletes aphidimyza* (Rondani, 1847), zatiaľ čo *Lestodiplosis* sp. bol zaznamenaný iba zriedkavo. Spomedzi ďalších prirodzených nepriateľov boli zaznamenané štyri druhy pestríc, *Episyrphus balteatus* (De Geer, 1776), *Melanostoma mellinum* (L., 1758), *Sphaerophoria rueppellii* (Wiedemann, 1830), *Sphaerophoria scripta* (L., 1758) (Diptera: Syrphidae) a jedna entomopatogénna huba, *Pandora neoaphidis* (Remaudière et Hennebert) Humber.

INTRODUCTION

The Russian wheat aphid, *Diuraphis noxia* (Kurdjumov) (Sternorrhyncha: Aphididae), native to central-western Asia and the eastern Mediterranean Basin [44], has become one of the most important insect pests of wheat (*Triticum* spp.) and barley (*Hordeum* spp.) in the world. Losses of crops and control costs reach several hundred million dollars per year [50].

D. noxia, previously unknown to Europe, was found in Macedonia [9] and Hungary [4] for the first time in 1989 and has become subsequently widespread within the Carpathian Basin [46]. It has been known since 2000

[31] in the Slovak Republic, colonizing spring barley in significant numbers and it exhibited its potential to reach a pest status for this host in southwestern Slovakia conditions [2].

Research and surveys in several countries have documented the natural enemies of *D. noxia*, to include hymenopterous parasitoids [e.g. 24, 29, 34, 37, 44] and several predator groups such as flies [e.g. 8, 19, 40], beetles [e.g. 11, 13, 24, 27, 33], and lacewings [e.g. 7, 32, 40]. Entomopathogenic fungi are also natural enemies of *D. noxia* [e.g. 5, 15], with previous documentation of their development in colonies of the aphid in spring barley in Slovakia [3].

While the seasonal development of entomophthoralean infection in colonies of *D. noxia* was evaluated on spring barley in detail in Slovakia [3], the role of parasitoids and dipteran predators in the regulation of *D. noxia* populations has not received any attention in Slovakia. The aim of this study was to identify the natural enemy guild of *D. noxia* in the Slovak Republic, and to record the relative abundances of aphid parasitoids and predators in spring barley fields in a region representing the northern limit of *D. noxia*'s expansion in Central Europe.

MATERIALS AND METHODS

The experiments were carried out from June to July of 2002 at three locations, Tehla (48°11'N 18°23'E), Maňa (48°09'N 18°17'E) and Nevidzany (48°17'N 18°23'E) of southwestern Slovakia. We used fields of spring barley, *Hordeum vulgare* L., which were all smaller than 4 ha. Field samples aiming to determine the complex of natural enemies on *D. noxia* were based on a single infested leaf of which the sample unit comprised. On each sampling date, 30 *D. noxia* infested leaves were collected randomly along the border of each field. Only exception was Maňa location (a location with the most *D. noxia*), where 50 infested leaves were taken to obtain more information about natural enemies. The sampling points were not permanently marked within the location. Thus, if a field was sampled repeatedly, the samples were taken from the same areas but never from the same point. In case of more aphid species (beside *D. noxia*) represented on one sample, the leaves were excluded from the survey.

Each infested leaf was examined in situ, and all living aphids, mummified aphids, mycosed aphids (a colour change or body overgrown and covered by mycelium) and predators were counted. Aphid cadavers overgrown with fungal pathogens were removed from colony, put in plastic tubes and transported to the laboratory, where cadavers were examined microscopically. The species of Entomophthorales were identified by external features and

Table 1. Population density of wingless and winged *Diuraphis noxia* aphids on spring barley at the three locations of south-western Slovakia in 2002.
 Tabuľka 1. Populačná hustota okridlených a bezkridlych vošiek *Diuraphis noxia* v porastoch jarného jačmeňa na troch lokalitách juhozápadného Slovenska v roku 2002.

Location/Sampling date	No. of leaves in sample ^a	Mean no. of wingless aphids per colony ± SEM	Mean no. of winged aphids per colony ± SEM
Maňa			
6/13/2002	50	21.04 ± 12.15	0
6/22/2002	50	10.7 ± 8.46	0.04 ± 0.28
6/30/2002	50	11.12 ± 7.69	0.36 ± 0.78
7/6/2002	50	11.92 ± 8.91	0.6 ± 1.14
Tehla			
6/19/2002	30	14.07 ± 7.41	0
6/26/2002	30	20.53 ± 13.97	0.4 ± 0.77
7/4/2002	30	12.74 ± 10.43	0.3 ± 0.6
Nevidzany			
6/19/2002	30	12 ± 6.9	0
6/26/2002	30	14.3 ± 8.03	0
7/4/2002	30	20.4 ± 13.74	0

^a one infested leaf represented one colony

^a jeden napadnutý list predstavoval jednu kolóniu

morphology of primary and secondary conidia, rhizoids and other taxonomically important fungal structures. The identification was based on the classification of Keller [28], and Humber [26].

Mummified aphids and living aphids from all samples were placed individually in plastic boxes with perforated top for aeration. They were transported to the laboratory and stored at room temperature until the parasitoids emerge. Emerging primary parasitoids (and hyperparasitoids) were identified according to Starý [43].

Hoverflies were identified using Stubbs [48] and Stubbs and Falk [49]. Voucher specimens of all parasitoids and predators are held at Comenius University, Department of Ecology.

The estimates of the parasitization percentage and fungal infection percentage of *Diuraphis noxia* were derived by dividing the number of aphids killed by parasitoids or fungi by the number of dead plus living aphids. This procedure provides only crude estimates of parasitization and fungal infection percentage; however, these were considered adequate for the purpose of the survey.

RESULTS

During June and beginning of July 2002, a total of 380 *D. noxia* colonies were sampled at the three weekly checked locations of southwestern Slovakia. The number of wingless aphids per colony ranged from 10.7±8.46 to 21.04±12.15 and winged aphids from 0 to 0.36±0.78 at all

three locations. Population was stable until the crop was harvested. Table 1 shows the details.

Hymenopteran parasitoids, dipteran predators and entomophthoralean fungi were dominant groups of natural enemies associated with *D. noxia* colonies.

Although from 7 to 70% of the *D. noxia* colonies were infested by hymenopteran parasitoids, the recovered samples indicated that parasitoid prevalence within colonies was low (mostly <5.5%) in all sites throughout the survey (Table 2). Only at the Maňa site, the 22 June samples indicated that parasitoid prevalence was higher (9.8%). The number of mummified aphids per colony varied from 0.1±0.4 to 1.3±1.34 (Table 2). Except of the last two sampling dates at Nevidzany, the prevalence of hymenopteran parasitoids was similar and remarkably stable at all sites (Table 2). 243 mummified aphids were found altogether in the samples collected from all fields. Emergence was observed in 72% of these mummies producing six primary parasites species identified as *Aphidius ervi* Haliday, *Aphidius rhopalosiphi* DeStefani, *Aphidius picipes* (Nees), *Diaeretiella rapae* (McIntosh), *Ephedrus plagiator* (Nees), *Praon volucre* (Haliday) (Hymenoptera: Aphidiidae) and two hyperparasites *Asaphes suspensus* (Nees) (Hymenoptera: Pteromalidae) and *Lygocerus* spp. (Hymenoptera: Ceraphronidae). *D. rapae* predominated, making up to 92.1% of the primary parasitoids that emerged. The following species of primary parasitoids, *E. plagiator*, *A. rhopalosiphi*, *A. ervi*, *P. volucre* and *A. picipes* accounted respectively

only for 3.1, 2.3, 1.8, 0.5 and 0.2%, of the total number of parasitoids reared. Hyperparasitism was very low; only 5 mummies produced hyperparasites (3 *A. suspensus* and 2 *Lygocerus* spp.) only at Maňa location.

The only predators consistently found feeding on aphids within colonies were dipteran larvae. Larvae of the family Cecidomyiidae were collected at all sites. The sampling revealed only low population of predaceous midge's larvae, usually between 0.06 ± 0.24 and 2.47 ± 3.6 larvae per colony. On the other hand 6 - 70% colonies revealed midge's larvae (Table 2). *Aphidoletes aphidimyza* (Rondani) was the most abundant species accounting for up to 88% of the total number of predaceous midges grown in the colonies. *Lestodiplosis* sp. was also found during the survey, but only on the June 26 and July 4 from Tehla.

Besides the above mentioned predaceous midges, seven syrphids species were found in connection with *D. noxia* colonies in Slovakia. These were *Episyrphus balteatus* (De Geer), *Melanostoma mellinum* (L.), *Sphaerophoria scripta* (L.), *Sphaerophoria rueppellii* (Wiedemann) (Diptera: Syrphidae). The species were rare and occurred randomly at all of the examined sites.

Out of the parasitic fungi, only one species *Pandora neoaphidis* (Remaudière et Hennebert) Humber was identified from *D. noxia*. The first samples collected on June 13 and on June 19 revealed infestation of colonies <13%. Fungal infection increased gradually and reached 30.4% on June 30 in Maňa, 12.3% on June 26 in Tehla and 23.9% on June 26 in Nevidzany.

DISCUSSION

The prevalence of hymenopteran parasitoids within *D. noxia* colonies was low, mostly <5.5% in Slovakia. This corresponds with the results of other authors; e.g. extremely low (approximately 1% overall) parasitism was recorded in Hungary [5], 1-2% in southwestern Idaho, USA [17] and <5% in Colorado, USA [51]. The only exception was Saudi Arabia, where parasitism ranged from 6.1 to 44.2% [1]. One possible explanation for such low parasitism could be the extreme rolling of the leaves of the aphid infested tillers so that only a few parasitoids were able to reach the well-protected aphids [51].

In central, southeast and east Europe, hymenopteran parasitoids guild of *D. noxia* consist of nine species, *Aphidius ervi*, *A. matricariae* Haliday, *A. picipes*, *A. rhopalosiphi*, *A. uzbekistanicus*, *Diaeretiella rapae*, *Ephedrus plagiator*, *Lysiphlebus fabarum* (Marshall) and *Praon volucre* [44]. Although a relatively large number of them (six species) have been recorded from the *D. noxia* in Slovakia during the study, only one species, *D.*

rapae seems to have potential as biological control agent. *D. rapae* was by far the most abundant hymenopteran primary parasitoid of *D. noxia* at all sites. Other primary parasitoids (*A. ervi*, *A. rhopalosiphi*, *A. picipes*, *E. plagiator* and *P. volucre*) were detected infrequently and hyperparasitoids (*A. suspensus* and *Lygocerus* spp.) have been only minor members of the hymenopteran fauna. All the species have not been previously recorded as *D. noxia* parasitoids in Slovakia.

Although *D. rapae* has been described as a generalist that attacks more than 60 aphid species [36], it can be a significant parasitoid only on certain aphids, such as cabbage aphid, *Brevicoryne brassicae* (L.) [18], green peach aphid, *Myzus persicae* (Sulzer) [25], *Chenopodium* aphid, *Hayhurstia atriplicis* (L.) [45] and similarly, as our research proves, also *D. noxia* (Antolin et. al. 2006). A high domination of *D. rapae* within *D. noxia* parasitoids same as in Slovakia was also reported e.g. in USA; where approximately >80% of *D. noxia* mummies resulted from attack by *D. rapae* in Idaho [16] and it also dominated in the west-central Great Plains [8], as well as in eastern Washington [34]; and in Switzerland [18]. Our data acknowledged that *D. rapae* is truly original parasitoid on *D. noxia* [44]. Contrary to the Switzerland, where *D. rapae* action was strongly affected by hyperparasitoids on cabbage aphid, in particular *Alloxysta* sp. [18], we found minimal activity of hyperparasitoids during the survey. As *D. rapae* has shown an ability to switch or alternate successfully between hosts [36], its levels of hyperparasitism were low and clearly associated with *D. noxia*. So we concluded that there are possibilities to improve its population in agroecosystems through enhancement of alternative host opportunities.

Surprisingly, a very limited literature dealing with dipteran predators of *D. noxia* exists in the world. Among the dipterans whose larvae prey on colonies, the most common were the polyphagous species of the genus *Leucopis* (Diptera: Chamaemyiidae) [6, 34, 51] and syrphid larvae (Diptera: Syrphidae) [29, 34, 51]. Even though; chamaemyiids were recovered from colonies in the Ukraine [6] and USA [8, 51], no chamaemyiids were found during the study in Slovakia and in France [24]. The syrphid larvae were common natural enemies of *D. noxia* in Colorado, USA, apparently being among the few predators capable of penetrating the rolled leaves [51]. *Episyrphus balteatus*, *Metasyrphus corollae* F. and *Sphaerophoria scripta* were the most abundant syrphids in the France [24]. *S. scripta* was the main syrphid preying on *D. noxia* colonies in the Ukraine [29]. The syrphids, *E. balteatus*, *M. mellinum*, *S. rueppellii*, *S. scripta* were rare and only randomly occurred at all checked sites in Slovakia. The occurrence of syrphids was more frequent

Table 2. Prevalence of hymenopteran parasitoids, entomopathogenic fungi and predaceous midges in *Diuraphis noxia* colonies in spring barley fields of the three locations of southwestern Slovakia in 2002.

Tabuľka 2. Rozšírenie blanokritídlych parazitoidov, dravých bylomorov a entomopatogénnych húb v kolóniách *Diuraphis noxia* v porastoch jarného jačmeňa na troch lokalitách juhozápadného Slovenska v roku 2002.

Location/Sampling date	% of leaves with mummified aphids	Mean no. of mummified aphids per colony ± SEM	% parasitization	% of leaves with mycosed aphids	Mean no. of mycosed aphids per colony ± SEM	% infection by fungi	% of leaves with predaceous midges	Mean no. of predaceous midges per colony ± SEM
Maňa								
6/13/2002	22	0.4 ± 0.9	1.8 (1052)	54	0.68 ± 0.71	3.1	6	0.06 ± 0.24
6/22/2002	70	1.3 ± 1.34	9.8 (535)	64	1.2 ± 1.64	8.9	38	0.78 ± 1.28
6/30/2002	38	0.8 ± 1.36	4.5 (556)	92	5.38 ± 4.73	30.4	48	1 ± 1.23
7/6/2002	36	0.84 ± 1.62	5.3 (596)	76	2.48 ± 2.28	15.6	34	0.74 ± 1.37
Tehla								
6/19/2002	33	0.43 ± 0.68	2.7 (422)	63	1.6 ± 1.94	9.8	0	0
6/26/2002	33	0.73 ± 1.87	3.0 (616)	77	3.03 ± 3.29	12.3	70	2.47 ± 3.6
7/4/2002	37	0.8 ± 2.09	5.3 (374)	67	1.53 ± 1.78	10.1	60	1.63 ± 2.27
Nevidzany								
6/19/2002	40	0.47 ± 0.63	3.3 (360)	73	1.87 ± 2.15	13.0	0	0
6/26/2002	0	0	0.0 (429)	87	2.73 ± 3.32	19.1	10	0.17 ± 0.53
7/4/2002	7	0.1 ± 0.4	0.4 (612)	93	6.43 ± 4.91	23.9	37	0.57 ± 0.9

in the severely damaged tillers. According to Rojo et al. [41], even though *E. balteatus* oviposition and larval behaviour make it a promising candidate for introduction of the *D. noxia* control this aphid has become an exotic pest.

The most abundant dipteran predator within *D. noxia* colonies in Slovakia was the predaceous midge, *Aphidoletes aphidimyza*, whose larvae are known as effective predators of various aphids in the fields; e.g. *Myzus persicae* Schultzer [10], *Brevicoryne brassicae* (L.) [39] as well as the cereal aphids, *Rhopalosiphum padi* (Linnaeus), *Sitobion avenae* (Fabricius) and *Metopolophium dirhodum* (Walker) [12, 42]. Paradoxically, no study has yet provided the information about association of *A. aphidimyza* with *D. noxia*. At the same time, cereal aphids had a higher nutritive value than e.g. *M. persicae* for the predaceous larvae [30]. In Slovakia, the predator was presented in colonies throughout the observation (Table 2). In the field was recorded mostly at least 5 times as much food available on individual leaves as it was necessary for larval development [38], so females tended to aggregate oviposition in high-density aphid colonies [47]. This is probably the reason of the low population density found during the study (0.06-2.47 larvae per colony). One larva is able to consume 4 out of 10 aphids in a Petri dish per day [10]. In the greenhouse, *A. aphidimyza* controlled the population of aphids efficiently in a delayed density-dependent manner [10].

Predation on parasitized *A. gossypii* in greenhouse by *A. aphidimyza* was observed. Production of parasitoids was lower when the predator was present [21]. We assume this is a possible explanation of low population of mummified aphids within colonies during the study.

Seven entomopathogenic fungi including five entomophthorales, *Pandora neoaphidis*, *Entomophthora planchoniana* Cornu, *E. chromaphidis* Burger et Swain, *Conidiobolus obscurus* (Hall et Dunn) Remaudière et Keller, *C. thromboides* Drechsler, *Neozygites fresenii* (Nowakowski) Remaudière et Keller, *Zoopthora radicans* (Brefeld) Batko and the hyphomycete, *Beauveria bassiana* have yet been determined of *D. noxia* worldwide [20, 21, 51]. Our results confirmed the previous findings of high *P. neoaphidis* prevalence within *D. noxia* colonies; e.g. incidence of infection reached high levels in Hungary [5], USA [14, 16], South Africa [23] and in Slovakia as well [3].

ACKNOWLEDGEMENTS

We are grateful to Marcela Skuhrová for providing a verification of predaceous midge's specimens, to Adriana

Králiková for determination of syrphids and Marek Barta for identification of fungal pathogens. This work was supported by the Grant Agency VEGA, project No 1/0260/08.

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