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NATURAL REGULATION OF THE APPLE LEAF-MINING MOTH POPULATIONS IN DIFFERENT TYPES OF HABITATS

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ABSTRACT

The species composition of parasitoids and the degree of parasitization of leaf-mining moths feeding apple trees in habitats of different anthropogenic pressure was studied during three growing seasons. Twenty six species of parasitoid hymenopterans from the superfamily *Chalcidoidea* and the families: *Braconidae* and *Ichneumonidae* were obtained. Parasitoids from the family *Eulophidae* played the greatest role in parasitization of leaf-mining moths. At untreated sites, hymenopterans parasitisized 15.5% of hosts, while at the treated orchard, parasitization rate was 5.2%. Among founded parasitoids, the highest ecological tolerance showed *Cirrospilus vittatus* and *Sympiesis gregori* (obtained only from the treated orchards) and *Sympies sericeicornis*, *Pnigalio pectinicornis* and *Apanteles xanthostigma* occurring in both studied types of habitats.

Key words: *Lepidoptera*, mining moths, *Hymenoptera parasitica*, *Chalcidoidea, Ichneumonidae*, *Braconidae,* parasitoid, parasitization, apple tree

INTRODUCTION

Mining moths are highly specialized group of phytophagous feeding inside plant tissue. The parasitizing form is a larval stage which feeding marks the leaves with mines of the shape so specific that it often helps to identify the species [6].

Many insects of this group are known as pests of fruit trees. The economic importance of species like *Leucoptera malifoliella*, *Phyllonorycter blancardella* and *Stigmella malella* has increased to such extent that in response, special pest management programs were created [16, 17, 18, 19, 20, 27]. The occurrence of insect parasites became effectively limited probably due to the frequent use of very toxic and non-selected insecticides causing the brake of natural barriers that normally sustain leaf-miner populations at low levels. Parasitoids of leaf-miners are also negatively influenced by environmental contamination caused mainly by industrial plants emitting harmful pollutants [4].

The aim of the study was to isolate parasitoid complex, reared from specific mining-moth species and to determine the degree of parasitization of the latter by hymenopteran parasitoids in habitats of different anthropogenic pressure.

Detailed information about species composition of leaf mining moths parasitoids were published earlier by Górska-Drabik [11].

MATERIAL AND METHODS

The study was performed during three growing seasons (1996–1998). The material was collected from apple trees growing in five different sites in Lublin.

The Ethnographic Museum of Rural History (site 1) – apple trees, here growing between historic buildings, are either several-decade old ones with branchy and irregular crowns or some several-year old plantings. Underneath the trees there is grass, and some ornamental plants in the vicinity.

The Botanical Garden of Maria Curie-Skłodowska University (site 2) – situated in the western part of Lublin. In the arboretum about 1,300 species of trees, shrubs and dwarf shrubs were planted, among them apple trees of fruit-growing varieties and about 86 taxa if decorative apple trees. The material was collected on decorative and fruit-growing species of apple trees.

The household garden in the residential district Sławin (site 3) – covers the area of 0.06 ha. It borders on other household gardens and a historic park overgrown with old trees. Ornamental plants, vegetable plants, shrubs and fruit trees (apple and prune trees) are grown here together, for instance different vegetable plants underneath the trees.

The monastery garden (site 4) in the city center – covers the area of nearly 1 ha. The garden is separated with a brick wall from housing estate and a mall. Vegetable, ornamental and fruit plants as apple, prune, pear trees and current bushes are grown here. Several-decade old apple trees with branchy crowns grow among vegetable and ornamental plants beds.

The experimental orchard of the University of Life Sciences (site 5) in the city outskirts covering 5 ha. Mines were collected from a plot on the area of 0,15 ha, planted with a mixture of more than a dozen varieties of 20 year old apple trees. The orchard was regularny treated with pesticides. The apple trees are systematically fertilized and agrotechnical measures regularly applied. Herbicide fallow in applied along the rows, while the strips between them are covered with grass mixture. During the study following insecticides were used in doses specified by producer: Owadofos 50 EC, Karate 025 EC, Sumithion 500 EC, Zolone 35 EC, Pirimor 50 DG, Mospilan 20 SP, Hostaquick 500 EC, Insegar 25 WP.

The orchard of Institute of Soil Science and Plant Cultivation in Jastków (site 6), situated 11 km away from Lublin. This apple orchard covers the area of 1 ha, with a 2000-10 000 trees/ha density. In the orchard herbicide fallows were kept in the rows of trees and grass in between them. There are fields and allotments in the vicinity where mostly hop, vegetable and ornamental plants were grown. The site was treated with insecticides as Fastac 10 EC, Cyperkil 25 EC, Bulldock 0.25 EC.

In sites 1-4 weren't applied any insecticide but in sites 5 and 6 pest management program was used. Site 6 was treated particularly intensively.

The leaves within reach and these visible mines only were collected from 3-6 apple trees chosen at random at each site. The material were collected every 10-14 days from May to October. In the case of *Callisto denticulella* the leaves with "folded margins", where older caterpillar fed, were also collected. In the laboratory, specimens were described to species on the basis of the look of the mine they caused. All the inhabited mines were then used for rearing, performed according to Borkowski [5]. The nomenclature of *Hymenoptera parasitica* follows Medvedev [22, 23, 24].

RESULTS

During the laboratory rearing that involved 3950 larvae and pupae of mining moths, 1875 imagines of parasitoids were obtained of which 1874 were identified to species. Twenty six species of parasitoid hymenopterans from families: Braconidae and Ichneumonidae and also superfamily Chalcidoidea were obtained. The most numerous group was *Chalcidoidea*, represented by 17 species, 5 other species belonged to *Braconidae* and 4 species to *Ichneumonidae* (Table 1).

The total parasitization of mining-moth larvae and pupae was 15.5% at untreated sites while it was 5.2% at treated orchard (Table 2).

The complex of *C. denticulella* parasitoids consisted of 17 hymenopterans species, in 1996-1998 they parasitized 12.5% of the host species reared, on average. The degree of parasitization was 7.4%, in 1996, 16.8% in 1997 and 12.8% in 1998 (Table 3). All parasitoids of this species came from untreated sites and the highest parasitization (14.7%) was stated in the Botanical Garden (Table 2).

Table 1. Proportional part (%) of species composition parasitoids reared from larvae and pupae of individual mining moths species occurring in apple trees: 1 – Ethnographic Museum of Rural History; 2 – Botanical Garden; 3 – household garden; 4 – monastery garden; 5 – experimental orchard

No	Species	Percentage of obtained specimens (%)	Site number
	***Callisto denticulella* (Thnbg.)**		
Ichneumonidae			
	Pimplinae		
1.	*Scambus calobatus* Grav.	11.4	1, 2, 3
	Gelinae		
2.	*Gelis* sp.	0.5	2
	Campopleginae		
3.	*Diadegma* sp. (*aff. germanica* Horstm., *aff. rectificator* Aubert)	0.5	3
4.	*Diadegma* sp. (*aff. neoapostata* Horstm., *aff. crataegellae* Thoms.)	5.0	1, 2, 3, 4
Braconidae			
	Microgasterinae		
5.	*Apanteles xanthostigma* Hal.	5.5	1, 2, 3
6.	*Apanteles longicauda* Wesm.	0.9	1
7.	*Apanteles bicolor* Nees	0.9	2
Chalcidoidea			
	Eulophidae		
8.	*Achrysocharoides latreillei* Curt.	58.4	1, 2, 3, 4
9.	*Cirrospilus diallus* Walk.	3.2	1, 3, 4
10.	*Elachertus inunctus* Nees	2.7	1, 2
11.	*Pediobius sp.*	0.5	4
12.	*Pnigalio pectinicornis* L.	0.5	2
13.	*Pnigalio soemius* Walk.	0.5	1
14.	*Sympiesis acalle* Walk.	3.6	1, 3, 4
15.	*Sympiesis gordius* Walk.	1.8	2, 4
16.	*Sympiesis sericeicornis* Nees	3.6	1, 2, 4
	Pteromalidae		
17.	*Habrocytus semotus* Walk.	0.5	3
	***Phyllonorycter blancardella* (Fabr.)**		
Braconidae			
	Microgasterinae		
1.	*Apanteles bicolor* Nees	0.6	2
2.	*Apanteles blancardellae* Bouché	0.3	3
Chalcidoidea			
	Eulophidae		
3.	*Achrysocharoides atys* Walk.	22.0	1, 2, 3
4.	*Chrysocharis* sp.	0.3	4
5.	*Cirrospilus diallus* Walk.	14.9	1, 2, 3, 4
6.	*Pnigalio pectinicornis* L.	1.9	2, 3, 4, 5
7.	*Sympiesis gregori* Bouček	0.3	5
8.	*Sympiesis sericeicornis* Nees	16.7	1, 2, 3, 4, 5
9.	*Sympiesis viridula* Thoms.	3.1	1, 2, 3, 4
	Encyrtidae		
10.	*Holcothorax testaceipes* Ratz.	39.9	1, 2, 3, 4
	***Stigmella malella* (Stt.)**		
Braconidae			
	Acaeliinae		
1.	*Acaelius subfasciatus* Hal.	7.7	2
Chalcidoidea			
	Eulophidae		
2.	*Cirrospilus diallus* Walk.	7.7	1
3.	*Derostenus* sp.	15.4	1, 3
4.	*Pnigalio pectinicornis* L.	69.2	1
	***Leucoptera malifoliella* (Costa)**		
Braconidae			
	Microgasterinae		
1.	*Apanteles xanthostigma* Hal.	85.7	5
Chalcidoidea			
	Eulophidae		
2.	*Pnigalio pectinicornis* L.	14.3	5
	***Stigmella desperatella* (Frey)**		
Chalcidoidea			
	Eulophidae		
1.	*Cirrospilus vittatus* Walk.	100	5

Table 2. Parasitiztion of particular mining moth species occurring on apple trees in different locations (1996-1998): site 1 – Ethnographic Museum of Rural History; site 2 – Botanical Garden; site 3 – household garden; site 4 – monastery garden; site 5 – experimental orchard, site 6 – orchard in Jastków

Type of habitat	Untreated orchards												Treated orchards					
Species	site 1			site 2			site 3			site 4			site 5			site 6		
	total	parasi-tized	parasi-tiztion ratio [%]	total	parasi-tized	parasi-tiztion ratio [%]	total	parasi-tized	parasi-tiztion ratio [%]	total	parasi-tized	parasi-tiztion ratio [%]	total	parasi-tized	parasi-tiztion ratio [%]	total	parasi-tized	parasi-tiztion ratio [%]
Stigmella desperatella (Frey)	13	1	-	8	0	-	3	0	-	0	-	-	3	1	-	-	-	-
Stigmella incognitella (H.-S.)	81	0	-	-	-	-	2	0	-	-	-	-	-	-	-	-	-	-
Stigmella malella (Stt.)	50	12	24.0	18	1	5.5	12	1	8.3	2	-	-	17	1	5.9	1	-	-
Stigmella oxyacanthella (Stt.)	1	0	-	8	0	-	1	0	-	-	-	-	-	-	-	-	-	-
Ectoedemia atricollis (Stt.)	60	0	-	5	0	-	6	0	-	-	-	-	-	-	-	-	-	-
Callisto denticulella (Thnbg.)	748	93	12.4	577	85	14.7	251	31	12.4	180	11	6.1	-	-	-	-	-	-
Phyllonorycter blancardella (Fabr.)	517	113	21.9	346	70	20.2	645	122	18.9	57	17	29.8	96	9	9.4	-	-	-
Leucoptera malifoliella (Costa)	6	1	-	7	1	-	0	-	-	0	-	-	229	7	3.1	-	-	-
Altogether	1476	220	14.9	969	157	16.2	920	154	16.7	239	28	11.7	345	18	5.2	1	-	-
Average parasitization	15.5												5.2					

Table 3. Parasitization of mining moths occurring at treated and untreated orchards (1996-1998)

Species		1996			1997			1998			Total		
		number of larvae and pupae		parasitiztion ratio [%]	number of larvae and pupae		parasitiztion ratio [%]	number of larvae and pupae		parasitiztion ratio [%]	number of larvae and pupae		parasitiztion ratio [%]
		total	parasitized		total	parasitized		total	parasitized		total	parasitized	
Untreated orchards	*Stigmella desperatella* (Frey)	2	0	-	7	1	-	15	0	-	24	1	4.2
	Stigmella incognitella (H.-S.)	0	0	-	66	0	-	17	0	-	83	0	-
	Stigmella malella (Stt.)	4	0	-	46	12	26.1	32	1	3.1	82	13	15.9
	Stigmella oxyacanthella (Stt.)	1	0	-	4	0	-	5	0	-	10	0	-
	Ectoedemia atricollis (Stt.)	0	0	-	66	0	-	5	0	-	71	0	-
	Callisto denticulella (Thnbg.)	484	36	7.4	535	90	16.8	737	94	12.8	1756	220	12.5
	Phyllonorycter blancardella (Fabr.)	182	50	27.5	171	18	10.5	1212	254	21.0	1565	322	20.6
	Leucoptera malifoliella (Costa)	1	0	-	2	0	-	10	2	-	13	2	-
Treated orchards	*Stigmella desperatella* (Frey)	1	0	-	-	-	-	2	1	-	3	1	-
	Stigmella malella (Stt.)	0	0	-	-	-	-	18	1	5.6	18	1	5.6
	Phyllonorycter blancardella (Fabr.)	2	0	-	-	-	-	94	9	9.6	96	9	9.4
	Leucoptera malifoliella (Costa)	78	6	7.7	-	-	-	151	1	0.7	229	7	3.1

The highest importance in the parasitization of *C.denticulella* (58.4%) had a gregarian chalcidoid – *Achrysocharoides latreillei* (Photo 1), which occurred at all four orchards free from chemical treatment. The highest number of parasitoid species (10) were stated at sites 1 and 2, the lowest (6) at site 4 (Table 1).

Photo 1. ***Achrysocharoides latreillei*** **Curt. (*Eulophidae*)**

The complex of parasitoids of *Ph. blancardella* involved 10 hymenopteran species, responsible for mean 20.6% parasitization of the host population (Tables 1, 3). The parasitization rate of *Ph. blancardella* at these sites was 27.5%, 10.5% and 21% in 1996, 1997 and 1998 respectively. In treated orchard the parasitization was 9.4%. The highest parasitization rate of this species was observed for the monastery garden (29.8%) (Table 2). Most abundant (39.9%), among parasitoids of this species was a chalcidoid *Holcothorax testaceipes* (Photo 2), the parasitoid found at all untreated sites (Table 1). The highest number of parasitoid species (7) was noted at sites 2 and 3, the lowest (5) at site 1 (Table 1). Nine species of parasitoids came from untreated orchards, three species from the treated one. Such species as *Pnigalio pectinicornis* and *Sympiesis sericeicornis* were common for the treated and untreated orchards.

Photo 2. ***Holcothorax testaceipes*** **Ratz. (*Encyrtidae*)**

Four parasitoid species were obtained from *S. malella*. At the untreated orchards they parasitized 15.9% of host individuals during the study (Tables 1, 3). The parasitization rate of *S. malella* was 26.1% in 1997 and 3.1% in 1998. The highest parasitization rate of this species was noted for site 1 – 24.0% (Table 2). The species most abundant was a chalcidoid *P. pectinicornis* (69.2%). The highest number of parasitoid species (3) was noted at site 1 (Table 1). One parasitoid from *S. malella* in the experimental orchard was obtained in 1998 but it could not be identified to species.

From *L. malifoliella* 2 hymenopteran species were reared, and they were responsible for 3.1% parasitization of host individuals in the experimental orchard (site 5). The parasitization rate counted for both parasitoids (*Apanteles xanthostigma* and *P. pectinicornis*) fluctuated from 0.7% in 1998 to 7.7% in 1996 (Table 3). The dominating species was *A. xanthostigma* (85.7%) (Table 1). Parasitoid species mentioned above occurred only in the treated orchard.

One parasitoid species (*Cirrospilus vittatus*) from *Stigmella desperatella* was obtained and it originated from the experimental orchard (Tab. 1).

The degree of parasitization of larvae and pupae was similar at each of untreated sites – 14.9% in the Ethnographic Museum, 16.2 % in Botanical Garden and 16.7% in household garden. The parasitization rate in the monastery garden was 11.7% (Table 2).

From larvae and pupae of 4 mining-moth species, collected from the experimental orchard, 5 parasitoid species were obtained: *C. vittatus*, *S. gregori*, *S. sericeicornis*, *A. xanthostigma*, *P. pectinicornis*. One specimen of parasitoid reared from *S. malella* has been unidentified (Table 1).

Two of them: *C. vittatus* and *S. gregori* occurred only in the treated orchard – site 5 (Table 1).

Non parasitoid was obtained from the material collected at the treated orchard in Jastków.

DISCUSSION

Investigations concerned with *Hymenoptera parasitica* were carried out in many science centers in Poland, but they were connected mainly with parasitoids of aphids and moths [3, 8, 9, 15, 31, 32]. As the knowledge of parasitoids of mining moths is rather poor. Actually, about 140 species of parasitoids belonging to *Hymenoptera* have been described so far as parasitoids of mining moths. Among them most numerous are represented by species of the superfamily *Chalcidoidea* and the families: *Braconidae* and *Ichneumonidae* [21, 33, 36]. The studies conducted in apple orchards also showed the presence of nearly 200 species of hymenopterans parasitoid, among which parasitoids of mining moths are numerous [26].

As a result of the study conducted in the territory of Lublin it was found out that the most numerous species representation had family *Eulophidae* – 15 species, while two other families (*Pteromalidae* and *Encyrtidae*) of the superfamily *Chalcidoidea* were represented by single species. Parasitoids of the family *Eulophidae* are especially abundant in the apple orchards infested by leaf-miners, *S. malella* and *Ph. blancardella* in particular [1, 26]. In the present study parasitoids from this family were reared from: *C. denticulella, Ph. blancardella, S. malella, S. desperatella* and *L. malifoliella*.

From about 30 species of *Braconidae*, known from apple orchards, only a few are parasitoids of leaf-mining moths [1, 26]. In the present study this family was represented by 5 species, among which *A. xanthostigma* was dominated.

Nearly 50 species of *Ichneumonidae* were found in orchards [26]. Not many of them, however, parasitize leaf-miners. It results from differences in body size – ichneumonids are too big to parasitize inside small larvae of mining moths [33].

Although during the present study 4 species of *Ichneumonidae* were obtained, among leaf-mining moths they had only one host species – *C. denticulella*. All ichneumonid species obtained in the study had been already described from orchards.

Most abundant parasitoid communities have been described from: *C. denticulella* – 10 species [37], *Ph. blancardella* – 23 species and from *L. malifoliella* – 13 species [13]. From Poland, the following number of species have been described from *Ph. blancardella* by particular authors: 15 species [14], 12 species [26] and 9 species [10], from *S. malella* – 9 species [26] and from *L. malifoliella* – 3 species [10].

The study revealed that the richest parasitoid fauna (17 species) was associated with *C. denticulella* – the species found only at the untreated orchards. *Ph. blancardella* also provided many (10) species of parasitoid hymenopterans while from *S. malella* only 4 species were obtained. The community of *L. malifoliella* parasitoids shown by Jenser and al. [13] comprised 13 species of parasitoid hymenopterans. Only 2 parasitoid species derived from *L. malifoliella* specimens collected from the experimental orchard. Such a small diversity in species composition of parasitoid complex may result from the accumulation of different environment contaminants (pesticides, traffic and industrial pollutants).

The efficacy of parasitoids can be high in relation to host population and ranges from 30% to 85% [2, 7, 12, 25, 30]. The parasitization rate of *Ph. blancardella* in Polish conditions was shown to reach 80-90%, and under such circumstances it is advisable to stop the pest's management [26, 28]. The parasitization degree of *S. malella* oscillates from 32% to 85% [26], while parasitization of *L. clerkella* may reach 20% [10]. The parasitization of particular moth species covered by the present study differed, and was the highest for *Ph. blancardella* – nearly 30%.

Within the complex of parasitoids reared from *S. malella*, the hymenopteran *P. pectinicornis* had the highest share in the parasitization. Other 3 species were not numerous and hardly contributed to limiting the number of the leaf-

miner. *C. vittatus* and *Chrysocharis prodice* are parasitoid species reported to play a key-role in regulating the population of *S. malella* [26], the former was reared in the present study from *Stigmella desperatella* while the latter was not stated.

Among parasitoids reared from *C. denticulella, A. latreillei* showed the highest share in parasitization. There were 4 species obtained from *Ph. blancardella*: *H. testaceipes*, *Achrysocharoides atys*, *C. diallus* and *S. sericeicornis* of similar parasitization rate. *H. testaceipes* was recorded earlier by Olszak [26] as the species dominating within the parasitoid community of *Ph. blancardella*. On the other hand, Goos [1] gives *Sympiesis latricornis* as the species most abundant among parasitoids of this leaf miner.

The obtained results seem to corroborate the statement [34, 35] that among the complex of entomophagous it is usual one or several species which are significantly important in regulating phytophagous populations. Other species, in spite of being numerous very often, are capable of totally damaging only an insignificant fraction of a pest population.

The sites free from any chemical treatment showed higher both the number of parasitoid species (24) and parasitization ratio (mean 15%) as compared to the orchard with chemical pest management (site 5), with 5 parasitoid species found and a 5% parasitization mean ratio.

Differences observed in parasitoids' occurrence, their efficacy in fact, for two types of the habitats studied probably resulted from the presence of host plants for imagines of parasitoids. Numerous plant species growing between trees at the sites untreated could serve as food supply whereas in orchards covered by pest management there were no blooming plants in the vicinity of apple trees.

Environmental contamination had a significant impact on the number of parasitoids in the studied area, irrespectively the type of environment. Urbanized areas belong to the most-transformed of anthropological environments, where traffic and local industry generated pollutions are key factors responsible for environment degradation [29]. The phenomenon of avoiding polluted areas by parasitoid hymenopterans was shown by Beiger and Woroszyło [4].

SUMMARY

1. A total number of 26 species of parasitoid *Hymenoptera* was obtained from moth leaf-miners. From mining moths collected from untreated sites reared 24 species of parasitoids. From orchards with chemical pest management, parasitoids (5 species) were obtained only for experimental orchard, none parasitoids were obtained from orchard in Jastków.
2. Parasitoids from the family *Eulophidae* played the greatest role in parasitization of leaf-mining moths.
3. The complex of parasitoids reared from particular mining-moth species comprised 1 to 17 species of parasitoid hymenopterans. The highest number of species, was obtained from *C. denticulella* and *Ph. blancardella.*
4. At untreated orchards, hymenopterans parasitisized 15.5% of hosts, while at the treated orchard, parasitization rate was 5.2%. The parasitization degree of particular mining moths species oscillated in succeeding years from 0.7% to 27.5%.
5. Among founded parasitoids, the highest ecological tolerance showed *C. vittatus* and *S. gregori* (obtained only from the treated orchard) and *S. sericeicornis*, *P. pectinicornis* and *A. xanthostigma* occurring in both types of studied habitats.

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