THE ROLE OF PARASITOIDS IN LIMITING THE HARMFULNESS OF LEAFROLLERS IN APPLE ORCHARDS

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Abstract: The aim of the studies was to determine significance of parasitoids as biocontrol agents against teafrollers in apple orchards. The studies were performed in different parts of Poland in 1994–2001. An average parasitization level of caterpillars amounted to ca. 8.6%, and it varied broadly up to individual orchards (from 2.4 to 32.4%). A natural parasitization level was strictly related to the intensity of orchards' protection against pests. Higher parasitization was observed in case of less protected orchards, and in those ones with a great number of leafrollers.

The greatest share in parasitizing leafroller caterpillars was stated for hymenopterans belonging to two families: Ichneumonidae and Braconidae. Populations of leafrollers were most effectively reduced by the following parasitoid species: *Ascogaster rufidens*, *Apanteles ater*, *Meteorus ictericus*, *Macrocentrus linearis* and *M. thoracicus* of Braconidae as well as *Campoplex mutabilis*, *Lissonota segmentator*, *Phytodietus segmentator*, *Itoplectis maculator*, *Diadegma armillatum* and *Apechthis rufata* of Ichneumonidae.

The results of conducted research also revealed preferences of particular parasitoids to parasitize some leafroller species. *A. rufidens* had the greatest share in parasitizing caterpillars of *Pandemis heparana*. Among hymenopterani parasitoids of *Archips rosanus*, the one most numerously occurring was *C. mutabilis*, also considered as the main parasitoid of *Acleris rhombana*. In parasitizing the leafroller *Adoxophyes orana* the greatest share fell to *M. ictericus* while in case of *Spilonota ocellana* – the most frequent parasitoid was *A. quadridentata*.

Tachinid flies were found to be of a minor importance in parasitization of leafroller caterpillars. They were only raised from four leafroller species, and their largest share fell in parasitization of *A. rosanus*.

Parasitation of *A. rosanus* eggs by *Trichogramma* sp. varied broadly depending on individual orchards and growing seasons, and ranged 0.8 to 33.9%.

Key words: leafrollers, hymenopteran parasitoids, caterpillars, pupae, braconids, ichneumonids

INTRODUCTION

A large number of parasitoid species are known to be able to reduce leafroller populations. Zerova *et al.* (1989) reported on over 200 of them. Balazs (1997) raised 67 parasitoid species as a result of her investigations on parasitization extent in caterpillars of both leafrollers and leafminers, feeding on apple leaves. Many authors shares the opinion that besides weather factors, parasitoids significantly affect the number of leafrollers in orchards (Hasselbach and Dickler 1984; Helsen and Bloomers 1989; Balazs 1991; Ryabchinskaya and Kharchenko 1995; Jenser *et al.* 1997).

Most of authors correspond with the opinion that hymenopterans are the most important parasitoids of leafrollers, especially the families Ichneumonidae, Chalcididae and Braconidae (Miczulski and Anasiewicz 1972; Charles 1974; Evenhuis 1974; Miczulski and Koślińska 1976; Angelova 1983; Galli 1984; Osman and Balazs 1988; Piekarska 1989; Piekarska and Kuśmierczak 1990; Balazs 1997; Athanassov *et al.* 1998; Piekarska-Boniecka *et al.* 1999).

An important factor of reducing the number of leafrollers is destruction of their eggs by oophagous parasitoids. *Trichogramma* sp. is considered as the most effective parasitoid, and is particularly concerned with those leafroller species which deposit eggs in large layers (*Archips rosanus* and *Pandemis heparana*). Dronka (1981a, b) reported that the parasitization degree of eggs reached 50%. *Trichogramma* sp. parasitizes eggs of other leafroller species too, e.g. *Adoxophyes orana*, *Hedya dimidioalba* and *Spilonota ocellana* (Kolmakova 1965; Bulut 1990).

In Poland not much work was done on the role of parasitoids in reducing the number of leafrollers occuring in apple orchards, and insufficient literature data are available (Miczulski and Koślińska 1976; Dronka 1981a, b; Piekarska 1989; Piekarska and Kuśmierczak 1990; Piekarska-Boniecka *et al.* 1999).

MATERIALS AND METHODS

With intent of broadening the knowledge on the role of parasitoids in regulating the number of leafrollers, samples of leaf clusters with detected symptoms of injuries caused by caterpillars of leafrollers were collected in

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apple orchards, located in various regions of Poland. Material for the study originated from unprotected orchards, and typical, commercial orchards protected against pests and diseases, (twice or three times a season) with a broad-spectrum of insecticides.

Colledted caterpillars were assorted according to species and then reared under the insectarium conditions, initially in beakers and next separately, in test-tubes, and this is allowed for accurate host deretmination of a particular parasitoid in most cases. Morever, each early spring (at the end of February) of 1997–1999, hibernating egg layers of *A. rosanus* were sampled for determining their parasitization degree by *Trichogramma* sp. Each egg layer was placed separately inside a litlle test-tube covered with a tampon. The hatching of larvae from the eggs was checked in laboratory conditions.

RESULTS

During four subsequent years (1994–1997) the sample of 8 668 leafroller caterpillars and pupae was collected for purposes of rearing. The share of pupae was inconsiderable (ca. 2%) and numerously presented species were as follows: *P. heparana* (35.6%), *A. rosanus* (26.5%), *S. ocellana* (14.4%), *Acleris rhombana* (14.4%), *A. orana* (4.8%) and *H. dimidioalba* (1.8%). Performed rearing resulted in 2626 (30.3%) alive moth of leafrollers. More than a half of caterpillars (51.8%) died due to unrecognized of factors, and a part of pupae (9.3%) dried up. Nearly 8.6% of sampled caterpillars decayed due to parasitization. Considerable differences in parasitization rate were stated between caterpillars collectedg from protected and unprotected orchards. Mean parasitization degree for unprotected orchards was 13.4% (range: 6.0–32.4%), while in case of protected orchards it was considerably lower, and amounted to 7.3% (range: 2.4–23.5%) (Table 1).

A higher parasitization degree was also stated for those orchards where the number of leafrollers was high, e.g. in 1995 at Grudynia Wielka 23.5%, in 1996 at Trzylatków 12.3%, at Długołęka 18.5% and Zduny 15.9%. With a decreased numbers of leafrollers in subsequent years, a lower parasitation level was observed in these orchards (Grudynia Wielka 1996 – 7.6%, 1997 – 6.5%; Długołęka 1997 – 2.4%). The lowest parasitization level of caterpillars sampled from protected orchards was stated in 1997 (4.7%), possibly as a result of a small number of leafrollers in that year comparing to preceding years.

Among the sampled caterpillars and pupae, 1490 imagines of parasitoids belonging to two orders were reared, viz. Hymenoptera (97.5%) and Diptera (2.5%). The register of acquired hymenopteran parasitoids comprised 37 species belonging to four families: Ichneumonidae, Braconidae, Eulophidae and Pteromalidae, with 22, 13, 1 and 1 species, respectively (Table 2).

Among ichneumonids strongly represented were: *Campoplex mutabilis* (Holmgr.) = *C. difformis* (Gmel.) –

Table 1. Parasitization level of leafroller caterpillars sampled in apple orchards in 1994–1997

Locality	Caterpillars							
	1994		1995		1996		1997	
	No.	[%]	No.	[%]	No.	[%]	No.	[%]
Unprotected orchards								
Skierniewice – Klin	20	15.0	208	8,7	398	6.0	85	9.4
Skierniewice – Podleśna	37	32.4	151	15,2	116	22.4	336	21.7
Skierniewice – Miła	300	12.0	–	–	–	–	–	–
Skoczykłody	30	10.0	–	–	–	–	–	–
Total	387	14.0	359	11,4	514	9.7	421	19.2
Protected orchards								
Mała Wieś	–	–	–	–	266	4.5	160	3.1
Trzylatków	–	–	405	6.7	187	12.3	39	7.7
Zalesie	–	–	–	–	133	8.3	40	2.5
Skierniewice-Sad Pomologiczny	–	–	–	–	289	6.9	32	6.3
Dąbrowice	137	11.7	680	3.8	974	11.1	296	8.3
Prusy	10	10.0	122	6.6	–	–	–	–
Długołęka	–	–	–	–	92	18.5	583	2.4
Zduny	–	–	–	–	44	15.9	–	–
Miłobądz	98	5.1	277	3.6	249	7.2	155	15.5
Tczew 1	–	–	–	–	63	3.2	–	–
Tczew 2	–	–	–	–	126	2.4	–	–
Grudynia Wielka	–	–	153	23.5	315	7.6	108	6.5
Albigowa	–	–	206	4.9	–	–	–	–
Residual orchards	23	17.4	66	6.1	659	8.8	–	–
Total	268	9.7	1 909	6.3	3 397	8.7	1 413	4.7
Protected & unprotected orchards All together	655	12.2	2 268	7.1	3 911	8.8	1 834	8.5

Table 2. Number of parasitoids obtained from caterpillars and pupae of leafrollers in 1994–1997

Taxon of parasitoid	No. of individuals				Total	
	1994	1995	1996	1997	No. of individuals	[%]
Braconidae (Hymenoptera)						
1. *Macrocentrus linearis* (Nees)	46	159	146	209	560	53.2
2. *Macrocentrus pallipes* (Nees)	–	85	–	–	85	8.1
3. *Macrocentrus thoracicus* (Nees)	1	3	13	2	19	1.8
4. *Apanteles ater* (Ratz.)	1	54	129	15	199	18.9
5. *Ascogaster rufidens* (Wesm.)	–	37	70	9	116	11.0
6. *Ascogaster quadridentata* (Wesm.)	3	8	2	3	16	1.5
7. *Meteorus ictericus* (Ness)	5	23	17	1	46	4.4
8. Others* (6 species)	3	7	1	–	11	1.1
Total	59	376	378	239	1 052	100.0
Ichneumonidae (Hymenoptera)						
1. *Campoplex mutabilis* (Holmgr.) = *C. difformis*	3	13	56	83	155	40.4
2. *Lissonota segmentator* (Grav.) = *L. rusticator*	–	2	52	7	61	15.9
3. *Lissonota errabunda* (Holmgr.) = *L. punctiventris*	32	–	–	2	34	8.8
4. *Phytodietus segmentator* (Grav.) = *P. polyzonias*	–	4	16	–	20	5.2
5. *Itoplectis maculator* (F.)	–	7	8	6	21	5.5
6. *Diadegma armillatum* (Grav.)	1	–	3	10	14	3.6
7. *Apechthis rufata* (Gmel.)	–	–	–	16	16	4.2
8. *Camposcopus canaliculatus* (Ratz.) = *Agrypon canaliculatus*	–	–	–	25	25	6.5
9. Others** (14 species)	6	3	18	11	38	9.9
Total	42	29	153	160	384	100.0
Pteromalidae (Hymenoptera)						
1. *Dibrachys cavus* (Walk.) (ex. *Apanteles ater*)	–	–	10	–	10	100.0
Eulophidae (Hymenoptera)						
1. *Elachertus artaeus* (Walk.)	–	7	–	–	7	100.0
Techinidae (Diptera)						
1. *Nemorilla floralis* (Fall.)	1	4	6	3	14	37.8
2. *Phebellia nigripalpis* (R.-D.)	–	3	9	3	15	40.6
3. *Bessa selecta* (Meig.)	–	1	1	2	4	10.8
4. *Pseudoperichaeta nigrolineata* (Walk.)	–	1	1	1	3	8.1
5. *Eumea mitis* (Meig.)	–	–	1	–	1	2.7
Total	1	9	18	9	37	100.0

* *Apanteles laevigata* (Ratz.), *Apanteles longicauda* (Wesm.), *Ascogaster annularis* (Nees), *Microdus dimidiator* (Nees), *Microgaster laeviscuta* (Thoms.), *Microgaster grandis* (Thoms.)

** *Itoplectis alternans* (Grav.), *Diadegma exareolata* Aubert, *Ephialtes rufata* (Gmel.), *Phaeogenes planifrons* (Wesm.), *Gelis cinctus* (L.), *Gelis instabilis* (Först.) = *G. agilis*, *Gelis areator* (Panz.), *Apophua bipunctoria* (Thunb.), *Teleutaea striata* (Grav.), *Pimpla turionellae* (L.), *Scambus brevicornis* (Grav.), *Pristomerus vulnerator* (Panz.), *Scambus calobatus* (Grav.), *Phytodietus* sp.

Table 3. Infestation of leafroller caterpillars by individual parasitoid species

Taxon of parasitoid	No. of host caterpillars	[%]
Braconidae (Hymenoptera)		
1. *Macrocentrus linearis* (Nees)	30	5.4
2. *Macrocentrus thoracicus* (Nees)	20	3.6
3. *Apanteles ater* (Ratz.)	38	6.9
4. *Ascogaster rufidens* (Wesm.)	99	18.0
5. *Meteorus ictericus* (Ness)	35	6.4
6. Others* (5 species)	17	3.1
Total	239	46.5
Ichneumonidae (Hymenoptera)		
1. *Campoplex mutabilis* (Holmgr.) = *C. difformis*	152	29.6
2. *Lissonota segmentator* (Grav.) = *L. rusticator*	23	4.4
3. *Lissonota errabunda* (Holmgr.) = *L. punctiventris*	9	1.7
4. *Phytodietus segmentator* (Grav.) = *P. polyzonias*	19	3.7
5. *Diadegma armillatum* (Grav.)	12	2.3
6. *Ephialtes rufata* (Gmel.)	6	1.2
7. *Apophua bipunctoria* (Thunb.)	5	1.0
8. Others (4 species)**	10	2.0
Total	236	45.9
Pteromalidae (Hymenoptera)		
1. *Dibrachys cavus* (Walk.) (ex. *Apanteles ater*)	1	0.2
Eulophidae (Hymenoptera)		
1. *Elachertus artaeus* (Walk.)	1	0.2
Techinidae (Diptera)		
1. *Nemorilla floralis* (Fall.)	14	2.6
2. *Phebellia nigripalpis* (R.-D.)	15	2.7
3. Others (3 species)***	8	1.4
Total	37	7.2
All together	514	100.0

* *Macrocentrus pallipes* (Nees), *Apanteles laevigata* (Ratz.), *Ascogaster quadridentata* (Wesm.) *Ascogaster annularis* (Nees), *Microgaster grandis* (Thoms.)
** *Diadegma exareolata* Aubert, *Teleutaea striata* (Grav.), *Scambus calobatus* (Grav.), *Phytodietus* sp.
*** *Bessa selecta* (Meig.), *Pseudoperichaeta nigrolineata* (Walk.), *Eumea mitis* (Meig.)

Table 4. Infestation of caterpillars of 5 leafroller species by individual parasitoid species in 1994–1997

Taxon of parasitoid	No. of host pupae	[%]
Braconidae (Hymenoptera)		
1. *Macrocentrus linearis* (Nees)	1	1.8
2. *Apanteles ater* (Ratz.)	1	1.8
3. *Apanteles laevigata* (Ratz.)	1	1.8
4. *Ascogaster quadridentata* (Wesm.)	1	1.8
5. *Ascogaster annularis* (Nees)	1	1.8
Total	5	9.0
Ichneumonidae (Hymenoptera)		
1. *Campoplex mutabilis* (Holmgr.)	7	12.8
2. *Itoplectis maculator* (F.)	21	38.3
3. *Itoplectis alternans* (Grav.)	1	1.8
4. *Apechthis rufata* (Gmel.)	16	29.1
5. *Apophua bipunctoria* (Thunb.)	2	3.6
6. *Pimpla turionellae* (L.)	3	5.4
Total	50	91.0
Together	55	100.0

40.4%, *Lissonota segmentator* (Grav.) = *L. rusticator* (Thunb.) – 15.9%, *L. errabunda* (Holmgr.) = *L. punctiventrs* (Thunb.) – 8.8%, *Camposcopus canaliculatus* (Ratz.) – 6.5%, *Itoplectis maculator* (F.) – 5.5%, *Phytodietus segmentator* (Grav.) = *P. polyzonais* (Foerst.) – 5.2%, *Apechthis rufata* (Gmel.) – 4.2% and *Diadegma armillatum* (Grav.) – 3.6%. The other 13 species constituted barely 5.3% of the whole raised ichneumonids. Among species from the family Braconidae most numerously occuring were*: Macrocentrus linearis* (53.2%), *Apanteles ater* (18.9%), *Ascogaster rufidens* (11.0%), *Macrocentrus pallipes* (8.1%) and *Meteorus ictericus* (4.4%). The remaining 8 species composed 4.5% of the total number of individuals of this family.

Dipteran parasitoids were represented by 5 species belonging to the family Tachinidae.

The bulk of parasitoids were endoparasitoids. To ectoparasitoids belonged only a few species from the genera *Phytodietus*, *Scambus* and *Gelis* (Ichneumonidae) as well as *Dibrachys cavus* from Pteromalidae and *Elachaertus artaeus* from Eulophidae. Species from the genera *Scambus* and *Gelis* as well as *Dibrachys cavus* could be concerned as parasitoids of the 2nd degree (hiperparasitoids). The majority of raised parasitoids were polyphagous in character, being able to develop themselves in caterpillars of lepidopterans belonging to various families. Only *Teleutea striata* showed to be an oligophagous species connected with the family Tortricidae. Species of the genus *Scambus*, besides lepidopteran caterpillars settled and developed also in insects belonging to other orders, e.g. Diptera.

The largest share in parasitization of leafroller caterpillars had hymenopterans from two families Ichneumonidae (45.9%) and Braconidae (46.5%) (Table 3). The most efficient parasitoids of leafroller caterpillars were: *A. rufidens, A. ater*, *M. ictericus*, *M. linearis* and *M. thoracicus* from the family Braconidae as well as *C. mutabilis*, *L. segmentator*, *P. segmentator* and *D. armillatum* from Ichneumonidae. The share of these nine species in parasitization of leafroller caterpillars amounted to 80.3%, including 47.6% of species ascribed to: *C. mutabilis* and *A. rufidens*.

Parasitoids raised from leafroller pupae, belonged to the following species: *I. maculator* (F.), *I. alternans* (Grav.), *A. rufata* (Gmel.), *C. mutabilis*, *Pimpla turionellae* (L.), *Apophua bipunctoria* (Thunb.), *A. ater* (Ratz.), *A. laevigata* (Ratz.), *M. linearis*, *A. quadridentata* (Wesm.) and *A. annularis* (Ness) (Tab.4). Four species: *A. rufata, P. turionellae, I. maculator* and *I. alternans* were raised from leafrollers' pupae only, the other ones also from leafrollers' carterpillars. The greatest part in parasitization of leafroller pupae fell to *I. maculator* and *A. rufata* of the family Ichneumonidae.

The result of conducted studies showed a some preferences of particular parasitoids parasitize determined leafroller species (Table 5). As far as caterpillars of *P. heparana* are concerned the largest share fell to the species *A. rufidens*. Among *A. rosanus* parasitoids most numerously occurred the species *C. mutabilis*. This species was also found to be the main parasitoid of *A. rhombana*, and 97% of its caterpillars were affected by it. In parasitization of *A. orana* the largest part fell to *M. ictericus*, while in *S. ocellana* – to *A. quadridentata*.

Tachinid flies were occasional parasitoids of leafroller caterpillars. They were raised from caterpillars of four leafroller species and had the largest share (12.1%) in parasitizing of the species *A. rosanus*.

In the studies conducted over 1997–1999 on parasitization of hibernating eggs of *A. rosanus* by the parasitoid *Trichogramma* sp. it was shown that an average level of infection was 9.1%, similary to parasitization of caterpillars, considerable differences were observed depending on orchards and growing season (Table 6). In 1999 the parasitization in two unprotected orchards was low and amounted to 0.8 and 2.9% respectively, and the percetage of eggs from which caterpillars of *A. rosanus* hatched was very high (ca. 95%). In two subsequent years parasitization of eggs increased significantly, and amounted to in 1999 32.4 and 33.9% in the above mentioned orchards. Together with increasing parasitization of eggs by *Trichogramma* sp., a proportional decrease was observed in the number of eggs from which caterpillar hatched. With the parasitization level of eggs 9.8 and 8.4%, found in 1998 in two unprotected orchards (Klin and Podleśna) the hatching succes amounted to 61.7 and 73.9% of eggs, respectively, while in 1999 with the higher egg parasitization level (32.4 and 33.9%) the hatching succes reached barely 31.4 and 30.2% of hibernating eggs.

Table 5. Infestation of caterpillars of 5 leafroller species by individual parasitoid species in 1994–1997

Taxon of parasitoid	No. of host caterpillars				
	Pandemis haparana	*Archips rosanus*	*Acleris rhombana*	*Adoxophyes orana*	*Spilonota ocellana*
1	2	3	4	5	6
Braconidae (Hymenoptera)					
1. *Macrocentrus linearis* (Nees)	30	–	–	–	–
2. *Macrocentrus pallipes* (Nees)	5	–	–	–	–
3. *Macrocentrus thoracicus* (Nees)	5	11	2	1	–
4. *Apanteles ater* (Ratz.)	13	22	1	1	–
5. *Apanteles laevigata* (Ratz.)	–	1	–	–	2
6. *Ascogaster rufidens* (Wesm.)	79	18	–	–	
7. *Ascogaster quadridentata* (Wesm.)	–	–	–	–	6
8. *Ascogaster annularis* (Nees)	–	–	–	–	2
9. *Meteorus ictericus* (Ness)	23	1	–	8	2
10. *Microgaster grandis* (Thoms.)	–	1	–	–	–
Total	155	54	3	10	14

1	2	3	4	5	6
Ichneumonidae (Hymenoptera)					
1. *Campoplex mutabilis* (Holmgr.) = *C. difformis*	20	34	91	4	1
2. *Lissonota segmentator* (Grav.) = *L. rusticator*	–	22	1	–	–
3. *Lissonota errabunda* (Holmgr.) = *L. punctiventrs*	–	8	–	–	–
4. *Phytodietus segmentator* (Grav.) = *P. polyzonias*	–	18	–	–	–
5. *Phytodietus* sp.	–	–	–	–	1
6. *Itoplectis maculator* (F.)	1	9	–	5	–
7. *Itoplectis alternans* (Grav.)	–	2	–	–	–
8. *Diadegma armillatum* (Grav.)	3	8	1	–	–
9. *Diadegma exareolata* Aubert	–	3	–	–	–
10. *Apechthis rufata* (Gmel.)	–	15	–	–	–
11. *Ephialtes rufata* (Gmel.)	–	5	–	–	–
12. *Apophua bipunctoria* (Thunb.)	5	–	–	–	–
13, *Teleutaea striata* (Grav.)	–	–	–	3	–
14. *Pimpla turionellae* (L.)	–	–	–	1	–
15. *Scambus calobatus* (Grav.)	–	2	1	–	–
Total	29	126	94	13	2
Pteromalidae (Hymenoptera)					
1. *Dibrachys cavus* (Walk.) (ex. *Apanteles ater*)	–	1	–	–	–
Techinidae (Diptera)					
1. *Nemorilla floralis* (Fall.)	3	10	–	–	1
2. *Phebellia nigripalpis* (R.-D.)	1	10	4	–	–
3. *Bessa selecta* (Meig.)	1	2	1	–	–
4. *Pseudoperichaeta nigrolineata* (Walk.)	–	2	–	–	–
5. *Eumea mitis* (Meig.)	–	1	–	–	–
Total	5	25	5	–	1
Together (537)	189	206	102	23	17

Table 6. Infestation of eggs of *A. rosanus by Trichogramma* sp. in 1999–2001

Year Locality	No. of eggs in total	Parasitized eggs [%]	% of eggs from which caterpillars hatched
1999			
Klin (UN)	339	2.9	95.6
Długołęka (P)	3 538	0.8	94.9
2000			61.7
Klin (UN)	1 221	9.8	
Podleśna (UN)	5 120	8.4	73.9
2001			
Klin (UN)	735	32.4	31.4
Podleśna (UN)	1 081	33.9	30.2
Długołęka (P)	1 945	4.2	78.8
Together	1 3979	9.1	73.7

P – protected orchard
UN – unprotected orchard

DISCUSSION

The results of presented study revealed that parasitoids should be considered as an important factor to reduce the number of leafrollers in apple orchards. Parasitization of leafroller caterpillars amounted to on average of 8.6%, however considerable differences relating to orchards and growing season (from 2.4 to 32.4%) were stated. A similar parasitization level of leafroller caterpillars (from 3 to 30%) was stated by Miczulski and Koślińska (1976) whilst Agelova (1983) reported a range of 9.6–13.8%, Balazs (1997) –10 to 20% and Athanasov *et al.* (1998) – a value of 13.8%. As far as parasitation degree of pupae is concerned, the values revealed by Piekarska (1989), Piekarska and Kuśmierczak (1990) and Piekarska-Boniecka *et al.* (1999) ranged from 22.5 to 33.3%.

The parasitization level of leafrollers was directly correlated with protection intensity of orchards against pests and with the occurrence of leafrollers themselves.

A greater parasitization level was observed in orchards, which were both protected poorer and characterized by a high number of leafrollers. Similar relationships were shown by de Jong (1958), Miczulski and Kośliński (1976) and Balazs (1997).

In general, among parasitoids of leafroller caterpillars the most numerous was *C. mutabilis* (Ichneumonidae). The species showed to be the most effective in parasitizing caterpillars of *A. rosanus* and *A. rhombana*, and had also a considerable share in *P. heparana*, *A. orana* and *S. ocellana*, i.e. practically in all important leafroller species occurring in apple orchards. The second important species was *A. rufidens* (Braconidae), which belonged to the most numerous parasitoid of *P. heparana*. *A. rufidens* had also a considerable share in parasitation of *S. ocellana* and *A. rosanus*. The importance of that species in parasitizing of leafroller caterpillars was reported by Miczulski and Kośliński (1976). According to these authors the greatest share in parasitizing of leafrollers in apple orchards had another species – *A. dimidiator* (Braconidae). It was possibly by due to the fact that in this period of time the pest species most numerously presented in the complex of leafrollers was *S. ocellana*, and *A. dimidiator* was just its main parasitoid. A different ranking of importance of leafroller parasitoids was presented by Piekarska (1989) and Piekarska and Kuśmierczak (1990) based on the results obtained from orchards of the province Wielkopolska. Probably the reason was that the bulk of parasitoids in their investigations had been obtained from pupae.

Several species raised by us were indicated as important leafroller parasitoids also by other authors. A high contribution of *I. maculator* to parasitization of pupae of four dominating leafroller species was ascertained by Piekarska-Boniecka *et al.* (1999). Studies performed by Wiąckowski and Wiąckowska (1961) as well as of Miczulski and Kośliński (1976) showed that the main role in parasitizing of caterpillars of *S. ocellana* played the hymenopteran *A. quadridentata*. A name of parasitoid species parasitizing caterpillars of leafrollers in Poland was very similar to the one in other European countries (Angelova 1983; Hasselbach and Dickler 1984; Reede *et al.* 1984; Mey 1987; Castellari 1990; Balazs 1997; Kienzle *et al.* 1997).

During the study period (1997–1999) in case of *A. rosanus* it was shown a relatively low level of parasitizing its hibernating eggs by *Trichogramma* sp. However, obtained results confirmed the opinion on egg parasitoids as an important factor for reducing the population size of that species. The occurrence of *A. rosanus* in apple orchards of Central Poland became a problem since 1995 and its highest intensity was observed in 1997. That year the highest egg parasitization was only 2.9%. In two subsequent years (1998 and 1999) the role of *Trichogramma* sp. in eggs parasitizing considerably increased, and at the same time a drop in the number of *A. rosanus* was observed. The number of hatched caterpillars decreased with the increase of the parasitization level of eggs of *A. rosanus*. Such relation was also shown by Dronka (1981b). Possibly, it was caused by secondary affecting the pest eggs by *Trichogramma* sp. The phenomenon of secondary parasitization of eggs by *Trichogramma* sp. was stated in the studies on parasitization of *Orgia antiqua* (Olszak 1992).

CONCLUSIONS

1. Parasitization of leafroller caterpillars on average amounted to ca. 8.6%, depending on individual orchards and varied from 2.4 to 32.4%.
2. A level of natural parasitization of leafrollers was directly related to their numbers and intensity of orchard's protection against pests. Higher parasitization was stated in less protected orchards and in those ones with a high number of caterpillars.
3. The greatest share in parasitizing leafroller caterpillars had hymenopterans from two families: Ichneumonidae and Braconidae. The following parasitoids reduced most intensively leafrollers, population: *A. rufidens*, *A. ater, M. ictericus*, *M. linearis* and *M. thoracicus* of the family Braconidae as well as *C. mutabilis, L. segmentator, P. segmentator* and *D. armillatum* of the family Ichneumonidae.
4. The greatest part in parasitization of leafrollers' pupae had *I. maculator* and *A. rufata* from the family Ichneumonidae.
5. The parasitization degree of *A. rosanus* eggs by *Trichogramma* sp. was considerably differentiated, depending on orchards and growing seasons, and it ranged from 0.8 to 33.9%.
6. Taking under consideration both egg and larva parasitization, parasitoids significantly reduced leaf rollers populations.

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REFERENCES

Angelova R. 1983. Parasites of leaf-rollers (subfam. Tortricinae, Lep.) in apple orchards. Nauchni Trudove, Vissh Selskostopanski Institut "Vasil Kolarov" 28: 95–102.

Athanassov A.Z., Jeanneret P., Charmillot P.J., Renard D. 1998. Parasitoids of codling moth and other leafrollers (Lepidoptera, Tortricidae) in apple orchards and forests in south-west Switzerland. Mitt. Schweiz. Entomol. Ges. 71: 153–162.

Balazs K. 1991. The causes of population increase of apple leaf roller (*Adoxophyes orana* F. v. R.). Növenyvédelem 27: 160–166.

Balazs K. 1997. The importance of the parasitoids in apple orchards. Biol. Agric. Hortic. 15: 123–129.

Bulut H. 1990. Investigations on the distribution and natural effectiveness of *Trichogramma embryophagum* (Hartig) in the eggs of *Hedya nubiferana* and *Spilonota ocellana* F. Proc. Turkish Nat. Congr. Biol. Contr.: 25–35.

Casteralli P.L. 1990. Research on the ethology and ecology of *Pandemis heparana* Denis et Schiff. (Lep. Tortricidae), in the province of Bolzano. Boll. Ist. Ent. Univ. Bologna 44: 75–88.

Charles P.J. 1974. The complex of parasites and predators of tortricids other than the codling moth and the summer fruit tortrix. Org. Int. Lutte Biol. Anim. Plantes Nuis. 3: 39–47.

Dronka K. 1981a. Effect of plant control measures on the effectiveness *Trichogramma embryophagum cacoeciae* March. parasitizing eggs of the leaf rollers *Archips rosana* L. Fruit Sci. Rep. 8: 75–84.

Dronka K. 1981b. Trials on the seasonal colonization of *Trichogramma embryophagum cacoeciae* March. for the control of *Archips rosana* L. Fruit Sci. Rep. 8: 85–90.

Evenhuis H.H. 1974. The parasitic Hymenoptera of injurious tortricids in apple orchards in the Netherlands. Org. Int. Lutte Biol. Anim. Plantes Nuis., 1974, 3: 53–59.

Galli P. 1984. Use of natural enemies to control the apple fruit tortrix. Obstbau-Weinbau 21: 289–292.

Hasselbach W., Dickler E. 1984. Importance of the leaf-roller *Pandemis heparana* Den. et Schiff. (Lep., Tortr.) in apple orchards. Biology - damage - control. Mitt. Biol. Bundesanst. Land-u. Forstwirtsch. Berl.-Dahlem. 223, 172 pp.

Helsen H., Blommers L. 1989. On the natural control of the summer fruit tortrix in mildly sprayed apple orchard. p. 905–910. In: Proc. Of 41 Symposium on Crop Protect. "Mededelingen van de Faculteit Landbouwwetenschappen Rijkuniversiteit Gent". 9 May 1989, Gent, Belgium.

Jenser G., Balázs K., Erdélyi Cs., Haltrich A., Kozár F., Markó V., Rácz V., Samu V. 1997. The effect of an integrated pest management program on the arthropod populations in a Hungarian apple orchard. Zahrad. Hort. Sci. (Prague) 24: 63–76.

Jong D.J., 1958. Het entomologisch onderzoek. Jversl. Proefstat. Fruit. Wilhelmin. 43–53.

Kienzle J., Zebitz C.P.W., Athanassov Z.A. 1997. Parasitoids of leaf roller species (Lepidoptera: Tortricidae) in apple orchards. Mitt. Dtsch. Ges. Alg. Angew. Ent. 11: 247–249.

Kolmakova V.D. 1965. The use of the local from of Trichogramma (*Trichogramma embriophagum* Htg) in the orchards of Transbaikalia. Zashchita Rastenii 24: 203–210.

Mey W. 1987. The complex of parasitoids of the European leaf roller, *Archips rosana* (Linne), in the fruit-growing area of Havelland. Beitr. Entomol. 37: 159–167.

Miczulski B., Anasiewicz A. 1972. Contributions to knowledge of the parasite insect fauna of the complex of tortrix moths (Tortricidae) occurring on black currant – *Ribes nigrum* L. and red currant – *R. rubrum* L. and on gooseberry – *R. grossularia* L. in the neighbourhood of Lublin. Pol. Pismo Entomol. 42: 211–222.

Miczulski B., Kośliński M. 1976. Parasites of leafrollers (Tortricidae) occurring in apple orchards in some regions of Poland. Pol. Pismo Entomol. 46: 165–178.

Olszak R.W. 1992. Hymenopteran parasitoids (Hymenoptera - Parasitica) of apple orchards – occurrence and role in reducing pests numbers. Diss. For Assoc. Professorship, Inst. Pom. Res. Floric., Skierniewice, Poland, 68 pp. [Polish with English summary].

Osman S.E., Balazs K. 1988. Observations on the parasitoid *Macrocentrus pallipes* Nees (Hymenoptera: Braconidae) in connection with its two hosts *Hedya nubiferana* Haw. and *Pandemis heparana* Den. et Schiff. (Lepidoptera: Tortricidae). Acta Phytopathol. Entomol. Hung. 23: 147–152.

Piekarska H. 1989. Ichneumonids (Hymenoptera: Ichneumonidae) parasites of leaf-rollers in apple orchards in Poznań viccinity. Rocz. AR Pozn. 202: 153–162.

Piekarska H., Kuśmierczak B. 1990. Contribution to the knowledge of the fauna of Ichneumonids (Hymenoptera, Ichneumonidae) parasiting of apples leaf-rollers in orchards in Poznań viccinity. Rocz. AR Pozn. 217: 53–64.

Piekarska-Boniecka H., Wilkaniec B., Trzciński P., Zawieja M. 1999. Parasitoids of *Ichneumonidae* family bred from larvae and pupae of leaf-rollers occurring in an apple orchard in the environs of Gostyn. Prog. Plant Protection/Post. Ochr. Roślin 39 (2): 452–454.

Reede R.H., Groendijk R.F., Wit A.K.H. 1984. Field tests with the Insect Growth Regulators, epofenonane and fenoxycarb, in apple orchards against leafrollers and side-effects on some leafroller parasites. Entomol. Exper. Applic. 35: 275–281.

Ryabchinskaya T.A., Kharchenko G.L. 1995. Parasitoids of leaf rollers in apple orchards. Zashchita Rastenii 7: 16–17.

Wiąckowski S., Wiąckowska I. 1961. Results of cultivating parasites of orchard entomofauna. Pol. Pismo Entomol. 31: 255–262.

Zerova M.D., Melika Z.G., Tolkanic W.I., Kotenka A.G. 1989. A specific richness of the parasitic Hymenoptera in apple-orchards of south-eastern Europe. Annotirowannyj spisok nasiekomych - parazitow listowiertok, powrieżdajuszczich Inf. Bull. WPS MOB 28: 7–69.

POLISH SUMMARY

ROLA PARAZYTOIDÓW W OGRANICZANIU SZKODLIWOŚCI ZWÓJKÓWEK LIŚCIOWYCH (TORTRICIDAE) W SADACH JABŁONIOWYCH

W latach 1994–2001 w sadach jabłoniowych różnych regionów Polski prowadzono badania nad rolą parazytoidów w ograniczaniu liczebności, a tym samym szkodliwości zwójkówek. Spasożytowanie gąsienic zwójkówek występujących w tych sadach wahało się w granicach od 2,4% do 32,4%. Poziom spasożytownia był ściśle zależny od intensywności zabiegów ochrony roślin oraz od liczebności populacji zwójkówek. Wyhodowane z gąsienic i poczwarek zwójkówek parazytoidy należały, przede wszystkim, do rodziny Braconidae i Ichneumonidae. Najczęściej i najliczniej występowały osobniki takich gatunków jak: *Ascogaster rufidens, Apanteles ater, Macrocentrus linearis, Macrocentrus thoracicus* (Braconidae) i *Campoplex mutabilis, Lissonota segmentator, Phytodietus segmentator, Itoplectis maculator, Diadegma armillata, Apechthis rufata* (Ichneumonidae).

Na podstawie przeprowadzonych badań stwierdzono, że niektóre z parazytoidów wykazują preferencje w odniesieniu do larw poszczególnych gatunków gospodarzy. W pasożytowaniu zwójkówki *Pandemis heparana* największy udział miała błonkówka *Ascogaster rufidens*, natomiast wśród parazytoidów gąsienic zwójkówek *Archips rosanus* i *Acleris rhombana* najczęściej występował *Campoplex mutabilis*.

Wśród parazytoidów zwójkówki *Spilonota ocellana* najczęściej występowały osobniki gatunku *Ascogaster quadrientata*, a w przypadku gąsienic *Adoxophyes orana* – parazytoid *Meteorus ictericus*.

W okresie licznego występowania zwójki *Archips rosanus* oceniono także wielkość spasożytowania jaj przez *Trichogramma* sp.– wahało się ono w granicach od 0,8% do 33,9%.