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PRIMARY PARASITOID AND HYPERPARASITOID GUILDS (HYMENOPTERA) OF GRAIN APHID (*SITOBION AVENAE* F.) IN NORTHERN POLAND

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Abstract: The aim of this study was to determine and compare the guilds of parasitic Hymenoptera associated with the grain aphid on rye and winter wheat in northern Poland. Of the seven species of primary parasitoids (Braconidae: Aphidiinae, Aphelinidae), parasitizing colonies of *Sitobion avenae,* the most numerous and most frequently occurring, included *Praon volucre*, *Aphidius rhopalosiphi* and *Aphidius uzbekistanicus*. Primary parasitoids of grain aphids were largely eliminated by hyperparasitoids, mostly of the families Megaspilidae (*Dendrocerus carpenteri*), Figitidae-Alloxystini (*Alloxysta* spp. and *Phaenoglyphis villosa*) and Pteromalidae (*Pachyneuron aphidis*, *Asaphes vulgaris*, *Coruna clavata*), but *D. carpenteri* and *Alloxysta* spp. belonged to dominants and subdominants, respectively.

Key words: Aphidiinae (Braconidae); hyperparasitoids; guilds; cereals.

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INTRODUCTION

Three aphid species occur most frequently on cereals in Poland: *Rhopalosiphum padi* L., *Sitobion avenae* F. and *Metopolophium dirhodum* (Wlk.) (Abo Kaf and Miczulski, 1991a; Pankanin-Franczyk, 1982; Sobota, 1992). The most abundant of them is the grain aphid, *Sitobion avenae* F. (Hemiptera: Aphidinea). Of the above-mentioned aphid species, the one most parasitized, mainly on wheat, is *S. avenae*, and much less often, *R. padi* (Sobota, 1992).

Guilds of primary parasitoids originate mainly from the subfamily Aphidiinae (Braconidae) (Abo Kaf, 1991; Abo Kaf and Miczulski, 1991b; Bilewicz-Pawińska and Pankanin-Franczyk, 1995; Kąkol and Miętkiewski, 2001; Pankanin-Franczyk, 1987; Sobota, 1992; Dębek-Jankowska and Barczak, 2005a; Rakhshani et al., 2013). The species composition of primary parasitoids of *S. avenae* is relatively constant; however, on individual species of cereals, they form guilds varying with respect to the number of species and their abundance, composed of 6-9 species of primary

parasitoids, 4-6 of which can be regarded as always occurring in aphid colonies on cereals, in both spring and winter.

Unfortunately, populations of primary parasitoids on cereal crops in Poland are to a large degree eliminated by hyperparasitoids, mainly of the families Megaspilidae (Ceraphronoidea) (two species), Pteromalidae (Chalcidoidea) (four species) and two species of Figitidae (Charipinae-Alloxystini, Cynipoidea: according to the systematics of Paretaz-Martinez et al., 2007). The degree of hyperparasitism is reported to be higher on winter cereals than on spring ones (Abo Kaf, 1991; Pankanin-Franczyk, 1982, 1987; Pankanin-Franczyk and Ceryngier, 1999; Sobota, 1992; Dębek-Jankowska and Barczak, 2005a, b). As observed in the case of primary parasitoids, the number of species of hyperparasitoids of *S. avenae* is larger than that of hymenopterans associated with other species of aphids feeding on cereals in Poland (Abo Kaf and Miczulski, 1991b).

The aim of this study was to determine and compare a qualitative and quantitative composition of guilds of parasitic Hymenoptera associated with the grain aphid, *Sitobion avenae* F. on rye and winter wheat in northern Poland.

MATERIALS AND METHODS

Sampling

Material for the study was both primary parasitoids (Aphidiinae, Aphelinidae), and hyperparasitoids (Ceraphronoidea, Chalcidoidea, Cynipoidea), reared from colonies of the grain aphid (*S. avenae*) collected from the settled fragments of cereal plants (mainly from spikes).

Samples were collected yearly in several parts of fields whose area was from about 6 to 10 ha as a part of private farms (under 20 ha) or as a part of large farms (more than 100 ha). Chemical protection against aphids or other cereal agrophages was not applied to the studied plantations. Observations of aphids and parasitic hymenopterans were conducted every 10 days, on average, from the moment of giving the first offspring by aphids migrating to cultivated fields, until the full maturity stage of cereals. Each time, an average of 100 fragments of plants was collected from each research area. Plant parts with aphid colonies were cut off and placed in plastic bags, and then transferred to the laboratory to breed parasitoids and hyperparasitoids.

Agricultural landscape with domination of private farms

Rye was grown here year by year. Both in 1997 and in 2000 winter wheat was grown after other cereal plants. It bordered on a mixture of legumes with cereals, and in the second year of the study with lupin, with a field track planted with single apple trees and an old orchard with grassy vegetation, sorrel and fruit trees. Both wheat and winter rye were grown here in the areas of private farms, each under 20 ha, which predominated in the agricultural landscape.

Agricultural landscape with domination of large farms

Rye and winter wheat crops located here were a part of a large farms (more than 100 ha). Crops were cultivated with the use of proper crop rotation and followed root crops or legumes (mainly lupins). Cultivated fields, being a part of large crops, were utilized in the

agricultural landscape, with a large proportion of roadsides, boundaries, midfield thickets and different kinds of the so-called environmental islands surrounding numerous homesteads.

Laboratory analyses and methods of data assessment

Aphids, together with mummies, were precisely counted in colonies, and then parts of plants colonized by them were placed in jars protected on the top by tight-fitting bolting cloth in order to breed primary parasitoids and hyperparasitoids. The jars were labeled and placed in glazed cabinets and kept at room temperature, ca. 19-22°C.

The isolated guilds of parasitic Hymenoptera were processed qualitatively (spectrum of species), whereas in order to present quantitative relationships, the numbers (L) and relative abundance (domination – D) of each taxon (percentage of the taxon in the total numbers of the given guild of primary parasitoids and hyperparasitoids together) were determined. The following domination classes were taken into consideration: dominants (D) – species accounting for more than 2.0% of the collected material in the given habitat; subdominants (SD) – species involving 10-2[illegible]% of the total number of specimens from the given research area and recedents (R) – species represented by less than 10% of all the individuals in the guild.

Table 1. Number (N) and relative abundance (domination – D) in the primary parasitoids and hyperparasitoids guilds of *Sitobion avenae* on winter wheat and rye on large farms.

	Genera / Species	Winter wheat								Rye								Sum	D (Σ)*
		1995		1996		1997		2000		1995		1996		1997		2000			
		N	D (%)	N	D (%)	N	D (%)	N	D (%)	N	D (%)	N	D (%)	N	D (%)	N	D (%)		
Primary parasitoids	Aphidiinae not determined					1	0.20	6	1.8	1	1.23					1	1.02	9	0.70
	Ephedrus plagiator (Nees)	1	2.63			2	0.40	4	1.2									7	0.55
	Praon volucre (Hal.)	1	2.63	8	6.25	40	7.98	37	11.0					5	6.25			91	7.10
	Lysiplebus fabarum (Marsh.)															3	3.06	3	0.23
	Aphidius zbekistanicus Lyzhetzki	13	34.21	51	39.84	165	32.90	40	11.90	10	12.35	2	10.53	8	10.00	16	16.33	305	23.79
	Aphidius ervi Hal.	10	26.32	20	15.63	98	19.60	16	4.70	29	35.80	3	15.79	19	23.75	43	43.87	238	18.56
	Binodoxys auctus (Hal.)	1	2.63	2	1.56													3	0.23
	Aphelinus asychis Wlk.			1	0.78	1	0.20	1	0.3	5	6.17							8	0.62
	Sum	26		82		307		104		45		5		32		63		664	51.79
Hyperparasitoids	*Asaphes vulgaris* Wlk.	1	2.63	3	2.34	25	4.99	17	5.0					1	1.25			47	3.67
	Pachyneuron aphidis Bouche	6	15.79	7	5.47	9	1.80	10	3.0							2	2.04	34	2.65
	Alloxysta spp.			15	11.72	43	8.58	91	27.0	7	8.64	6	31.58	8	10.00	5	5.10	175	13.65
	Phaenoglyphis villosa Htg.	1	2.63			3	0.60	8	2.4					1	1.25			13	1.02
	Dendrocerus carpenteri Curtis	4	10.53	21	16.41	114	22.75	65	19.3	29	35.80	7	36.84	34	42.50	16	16.33	290	22.62
	Tetrastichus sp.							42	12.4			1	5.26	4	5.00	12	12.24	59	4.60
	Sum	12		46		194		233		36		14		48		35		618	48.21
	Total hymenopterans	38		128		501		337		81		19		80		98		1282	100.00
	Total No. of samples	296		390		475		1483		238		252		236		646		4016	

*/ Relative abundance value (D) for the particular species, as aggregate for all the material (hymenopterans) from large farms

RESULTS AND DISCUSSION

Guilds of parasitic Hymenoptera associated with the grain aphid *S. avenae* included seven species of primary parasitoids and at least nine species of hyperparasitoids in total. Dominants, irrespective of the cereal species and locality, included two species of the genus *Aphidius*: *Aphidius uzbekistanicus* Luzhetzki, which was the most numerous on winter wheat (from 54% of all individuals of the genus *Aphidius* on private farms to 65% on large farms), and *Aphidius ervi* Hal. on rye – 72% on large farms and 61% on private farms (Tables 1 and 2). One of those occurring more numerously was *Praon volucre* Hal., which only in some years of the study was a subdominant on wheat, especially on private farms (Tables 1 and 2). In general, much more primary parasitoids were found on wheat than on rye, which was particularly noticeable on large farms, where on average in the year about 130 specimens were isolated, compared to only 36 on rye plantations (Table 1). On private farms, these values were more similar and amounted to, on average, 164.5 parasitoids on wheat and 113 on rye (Table 2). The numbers of hymenopterans isolated from colonies of *S. avenae* on wheat and rye were recorded; the season average was 320.5 primary parasitoids and hyperparasitoids on large farms, and 772 on private farms. This indicates that on plantations of rye and winter wheat almost 2.5 times more parasitic hymenopterans occurred on private farms than on large farms (Tables 1 and 2).

The number of primary parasitoid species associated with the grain aphid recorded by many authors is varied, depending on the region where the study was carried out (Dean et al., 1981). Most often eight species are mentioned. These are *A. uzbekistanicus*, *A. ervi*, *Aphidius avenae* Hal., *Aphidius rhopalosiphi* De Stefani-Perez, *A. matricariae* (Hal.), *Ephedrus plagiator* Nees, *P. volucre*, *Lysiphlebus fabarum* (Marsh.), *Diaeretiella rapae* (M'Intosh), *Lysiphlebus testaceipes* (Cresson) (Bilewicz-Pawińska and Pankanin-Franczyk, 1995; Ceryngier and Pankanin-Franczyk, 2001; Chambers et al., 1986; Coaker, 1980; Kröber and Carl, 1991, Pankanin-Franczyk, 1995b; Sobota, 1992; Starý, 1976; Lumbierres et al., 2007). Summing up the study of primary parasitoids of grain aphids in Serbia, Tomanović et al. (2008) recorded *A. uzbekistanicus* and *A. ervi* as generally the most abundant primary parasitoids of *S. avenae*, while *E. plagiator* and *P. volucre* were much less common. The qualitative analysis showed the occurrence of seven species found in the neighborhood of Bydgoszcz (northern Poland), of which only three (*A. uzbekistanicus*, *A. ervi* and *P. volucre*) occurred in each year of the study. Pankanin-Franczyk (1982) reports that apart from these, the most constant in Mazovia also include *A. avenae* and *E. plagiator*. Of *Aphidiinae,* the aphid *S. avenae* was attacked the most heavily in all the years of the study by two species, *A. uzbekistanicus* and *A. ervi*, the former of which deserves particular attention. It belongs to the most important species attacking aphids on both wheat and rye (Pankanin-Franczyk, 1978). Rabasse and Dedryver (1983) reported that this is an unimportant factor regulating the numbers of aphids on cereals; however, the present results (from northern Poland) are not in full agreement with these authors. *A. uzbekistanicus* is one of the most essential species commonly occurring in cultivated fields and meadows, also penetrating the edges of forests. Its hosts, apart from *S. avenae,* can be *Aphis craccivora* Koch., *Sitobion fragariae* Wlk., *Schizaphis graminum* Rond. and *M. dirhodum* (Pankanin-Franczyk, 1978; Sobota, 1992). Although Kröber and Carl

(1991) report that it shows preferences towards some species of aphids (it attacks *M. dirhodum* more frequently than *S. avenae*), they express the reservation that in the period of conducting the study the aphid *M. dirhodum* occurred in small numbers. In this study *A. uzbekistanicus* may be also regarded as the most constant element of primary parasitoid guilds, together with a second numerous species, *A. ervi*, which is confirmed by other authors (Abo Kaf, 1991; Abo Kaf and Miczulski, 1991b; Bilewicz-Pawińska and Pankanin-Franczyk, 1995; Chambers et al., 1986; Coaker, 1980; Kąkol and Miętkiewski, 2001; Kröber and Carl, 1991; Pankanin-Franczyk, 1982, 1987, 1995b; Pankanin-Franczyk and Ceryngier, 1999; Sobota, 1992; Starý, 1976). A species very similar to *A. uzbekistanicus* with respect to food requirements is *A. rhopalosiphi*, which, however, prefers to attack more numerous colonies of *S. avenae*: moreover, it more often affects green forms of that aphid (Hågvar and Hofsvang, 1991; Kröber and Carl, 1991; Sobota, 1992). *A. ervi*, in turn, has a limited range of hosts, and these are *Acyrthosiphum pisum* H., *Microlophium carnosum* L., *S. avenae*, *M. dirhodum* (Abo Kaf and Miczulski, 1991b; Pankanin-Franczyk, 1978, 1987; Powell and Wright, 1992). In addition, it often plays a

Table 2. Number (N) and relative abundance (domination – D) in the primary parasitoids and hyperparasitoids guilds of *Sitobion avenae* on winter wheat and rye on private farms.

	Genera / Species	Winter wheat				Rye				Sum	D (Σ)*
		1997		2000		1997		2000			
		N	D (%)	N	D (%)	N	D (%)	N	D (%)		
Primary parasitoids	Aphidiinae not determined	1	0.33	1	0.33	1	0.16	2	0.64	5	0.32
	Ephedrus plagiator (Nees)			8	2.61	11	1.77	26	8.31	45	2.92
	Praon volucre (Hal.)	52	17.16	54	17.59	20	3.22	20	6.39	146	9.46
	Aphidius zbekistanicus Luzhetzki	77	25.08	39	12.70	36	5.80	20	6.39	171	11.08
	Aphidius ervi Hal.	65	21.45	32	10.42	59	9.50	29	9.27	185	11.98
	Aphelinus asychis Wlk.	1	0.33			1	0.16	1	0.32	3	0.19
	Sum	195		134		128		98		555	35.95
Hyperparasitoids	Chalcidoidea not determined			1	0.33					1	0.065
	Asaphes vulgaris Wlk.	13	4.29	17	5.54	25	4.03	18	5.75	73	4.73
	Coruna clavata Wlk.					1	0.16			1	0.065
	Pachyneuron aphidis Bouche			18	5.86	4	0.64	45	14.38	67	4.34
	Syrphophagus aphidivorus (Mayr)							15	4.79	15	0.97
	Alloxysta spp.	52	17.16	62	20.20	100	16.10	25	7.99	239	15.48
	Phaenoglyphis villosa Htg.	5	1.65	27	8.79	4	0.64	2	0.64	38	2.46
	Dendrocerus carpenteri Curtis	37	12.21	45	14.66	358	57.65	106	33.87	546	35.36
	Eulophidae not determined					1	0.16	1	0.32	2	0.13
	Tetrastichus sp.	1	0.33	3	0.98			3	0.96	7	0.45
	Sum	108		173		493		215		989	64.05
	Total hymenopterans	303		307		621		313		1544	100.00
	Total No. of samples	393		1026		520		619		2558	

*/ Relative abundance value (D) for the particular species, as aggregate for all the material (hymenopterans) from private farms.

subdominant role in colonies of grain aphid, and is also the main enemy of pea aphid on alfalfa and clover (Sobota, 1992; Starý, 1976).

The presence of *P. volucre*, the third species of parasitoid in terms of the population numbers bred from grain aphid, was recorded in 1997 and 2000 on private farms on both studied cereal species, whereas it occurred more numerously on wheat crops, which was also found at the same time on large farms. It is interesting, however, that on rye crops it occurred in small numbers at that time; only single specimens were recorded here in 1997. This could indicate the existence of some preference towards the species of the aphid host plant. *P. volucre* is probably connected to the environment of plants that are the main hosts for aphids (Vorley, 1986) and its presence does not depend greatly on the location of crops in the agricultural landscape (Pankanin-Franczyk, 1987, 1995b). This regularity was confirmed in the results of the present study. For *P. volucre* the typical environment is forest (Barczak, 1988; Sobota, 1992), but it also occurs in orchards (the wheat plantation on private farms and on large farms in 2000 bordered on an orchard), and on cereal crops (Olszak, 1999). *P. volucre*, which belongs to the group of oligophages (Barczak, 1991; Barczak et al., 2013), besides *S. avenae* also parasitizes *Dysaphis plantaginea* (Pass.), *Hyalopterus amygdali* (Blanchard), *H. pruni*, *Acyrthosiphon caraganae* (Cholodkovsky) and *Aulacortum solani aegopodii* Börner, *Brevicoryne brassicae* L., *R. padi*, *Macrosiphum euphorbiae* (Thomas), *Myzus persicae* L., *A. craccivora*, *A. gossypi*, *A. pisum* and others (Pankanin-Franczyk, 1978; Tomanović et al., 2008; Lumbierres et al., 2007).

In all the years, small numbers of representatives of the family *Aphelinidae* were also recorded, however, infestation with *S. avenae* was lower. The most often recorded species of this family, in colonies of *S. avenae*, is *Aphelinus asychis* Wlk. (Coaker, 1980; Sobota and Gabryś, 1999a). However, it occurs quite rarely on cereal crops. Its abundance on crops of winter wheat in Poland was observed by Sobota and Gabryś (1999b). However, the occurrence of *Aphelinus* genera attacking some cereal aphid species, especially in winter and spring, is noteworthy (Lumbierres et al., 2007). During these seasons, its occurrence was similar to, or even higher than that of *P. volucre*, a very common occurrence on cereal aphids in Europe. Generally, *Aphelinus* spp. has been reported as an occasional primary parasitoid of cereal aphids in Europe, e.g. in Spain and France, but not in Serbia (Tomanović et al., 2008) nor in the area we investigated.

In the case of hyperparasitoids, irrespective of the cereal species the most numerously occurring were *D. carpenteri* (the numbers of populations of this species, in total and on average for all the years of the study and for both cereal species, were estimated at 836 specimens (45.38 %) – in some growing seasons it belonged to subdominants and dominants), and *Alloxysta* spp., which, like the former species, in some seasons was subdominant and in others dominant (Tables 1 and 2). In addition, a relatively large number of hyperparasitoids of the family *Pteromalidae* is noteworthy. Generally, a larger species spectrum of these insects was found on private farms; in guilds of hymenopterans on rye crops, those numbers were similar (Tables 1 and 2). However, irrespective of location of the plantation and the cereal species, the numbers of hyperparasitoids on cereal crops were large and thus the hyperparasitism (percentage of hyperparasitoids in the guild) almost in each case

reached nearly 50% or more (Tables 1 and 2). A slightly higher degree of hyperparasitism was recorded for all the years on wheat plantations on private farms (46%) than on large farms (43.8%), while in the case of rye, this difference was still more distinct: in guilds of parasitoids on rye on private farms nearly 74% of hyperparasitism was observed compared to 53.5% on large farms (Tables 1 and 2). A more precise analysis of hyperparasitism in guilds of parasitoids of *S. avenae* was presented in a separate study (Dębek-Jankowska and Barczak, 2005b). For comparison – in Serbia, of the cereal aphids hyperparasitoids, six species predominated with *Asaphes suspensus* (Nees) and *D. carpenteri* generally the most abundant (Tomanović et al., 2008). However, *D. carpenteri* and *A. suspensus* (Pteromalidae) were the most abundant mummy hyperparasitoids of the most numerous aphid, *S. avenae*, in the present study. Hyperparasitoids are usually polyphages, showing an ability to adapt quickly to a new host, thanks which they can easily migrate between agrocenoses and, consequently, they are main factors affecting the dynamics of primary parasitoid populations on cereals (Barczak, 1993; Kröber and Carl, 1991; Pankanin-Franczak, 1995a). The study by Sullivan (1986), however, indicates a possibility of food specialization occurring within this group. The author suggests that it exists, particularly in the case of endohyperparasitoids, which include, among others, the genus *Alloxysta*, whereas the occurrence of food specialization in ectohyperparasitoids, to which the genera *Dendrocerus*, *Asaphes* and *Pachyneuron* belong, is rather doubtful (Sullivan, 1988). One way or another, the hyperparasitoid complex of cereal aphids in Europe is relatively similar and, mainly, they are *Alloxysta* spp., *Phaenoglyphis* sp., *Asaphes* spp., *Coruna* sp., *D. carpenteri* and others (Tomanović et al., 2008; Lumbierres et al., 2007). However, the relative abundance of the individual species can be different in given cases.

Determination of the parasitic Hymenoptera guild structure of the given aphid species, the effectiveness of those guilds in relation to the host population, dispersion abilities of primary parasitoids (penetration of different types of habitats), their food specificity and synchronization of their appearance on spontaneously growing vegetation, with the host population in agrocenoses are necessary criteria for the assessment of the usefulness of primary parasitoids for pest control within the framework of the so-called IPM (Barczak, 1993). The essential problem of hyperparasitism must also be taken into account (Sullivan, 1987). At present, the main way of stimulating the activity of natural enemies in the agricultural environment should be protection of the current plant reservoirs (wild growing aphid host plant species) for beneficial organisms and creating new ones by increasing the proportion of so-called semi-natural habitats. Thus, the resources (population numbers, habitats) and possibilities of increasing the activity of these aphidophages (so-called augmentation) can be protected and developed, respectively (Ehler, 1990; Barczak, 1993; Kajak, 1998).

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