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THE COMPOSITION AND ROLE OF PARASITOIDS IN REDUCING POPULATION DENSITIES OF DIAMONDBACK MOTH *PLUTELLA XYLOSTELLA* L. ON DIFFERENT CABBAGE VEGETABLES

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Abstract: In 1993–1997, 990 pupae of diamondback moth (*Plutella xylostella* L.) were collected from nine different varieties of *Brasica oleracea* L., grown on experimental farm near Kraków. Only 234 moths (23.6%) were recovered from the cocoons. The most important factor reducing the population of DBM was parasitization (65.1%). It varied between the years of observation and oscillated from 60% to 90.3%. Sixhundred and fourty four specimens of parasitic wasps belonging to 11 species from families: *Ichneumonidae* (5 species), *Braconidae* (3 species), *Pteromalidae* (2 species) and *Eulophidae* (1 species) were reared out. In each year of observations the most abundant species among DBM parasitoids was *Diadegma fenestralis* Holmgr. as it constituted 71.4% of all of the wasps reared. In the years 1994 and 1996 with low abundance of diamondback moth, *D. fenestralis* was the only species parasitizing 66.7% and 89.5% of the pest larvae.

Key words: *Plutella xylostella* L., parasitoids, cabbage vegetables

INTRODUCTION

Plutella xylostella L. (*Lepidoptera, Plutellidae*), commonly known as the diamondback moth (DBM), is one of the most important pests of cruciferous vegetables. It can cause serious economic losses if not controlled. Naturally occurring parasites are important factors regulating population densities. The use of natural enemies might become the effective alternative methods of pest control in the near future. More than 90 species of parasites attack the larvae and pupae of the DBM in different parts of the world. Numerous studies have shown that the population of the DBM can be reduced by parasitoids belonging to genus *Diadegma* (Ali and Karim 1995; Iga 1997; Harcourt 1960; Łagowska 1981; Rahn and Chevallerau 1996; Waage 1983; Wiech and

Jankowska 1999, Wiech and Kałmuk 2002, 2003). Other parasitoids, mostly *Braconidae* and *Eulophidae* are also mentioned as effective in decreasing the number of *P. xylostella* larvae (Tobias 1971; Mustaque and Mohyuddin 1987; Talekar 1996; Wiech and Kałmuk 2002). The aim of this work was to study the level of parasitization of DBM larvae through out the growing season as well as the parasitoid composition on different cabbage botanical varieties.

MATERIALS AND METHODS

Observations on the occurrence of *P. xylostella* and its parasitoids were carried out in the Plant Protection Experimental Station in Mydlniki near Krakow in 1994–1997, on a typical brown soil with pH 6.5 and C_{org} content 1.8%. The following nine late cruciferous vegetables: Savoy cabbage cv. Vertus, white cabbage cv. Amager, red cabbage cv. Langendijker, Brussel sprouts cv. Maczuga, cauliflower cv. Pionier, blue kohlrabi cv. Masłowa, white kohlrabi cv. Delikates, kale cv. Zielony Kędzierzawy and broccoli cv. Piast, (except 1993), were grown on plots of 30 m^2 each, in four replications. Every plot comprised 90 plants (10 plants of each cabbage variety, 60 x 60 cm spacing), planted in such a way so that the plants of the same kind never adjoined. Near the experimental plots other vegetables such as broad bean, tomatoes, pepper, carrot, onion and red beet were cultivated. No insecticidal treatment was applied. During the observations conducted every 3–4 days, 12 plants from each vegetables were inspected. The collected pupae of the diamondback moth were kept separately in glass vials at the laboratory until either parasitoid or moth emerged. Parasitoids were identified by prof. dr hab. Bartłomiej Miczulski from Agriculture Academy in Lublin. In order to evaluate the significance of differences, the Duncan test ($\alpha < 0.05$) was used.

RESULTS AND DISCUSSION

The DBM was observed in each year of the experiment and occurred on all studied vegetables. Each year the highest number of caterpillars was noted on Brussel sprouts. In all years of the research (except 1997), the least infested among the tested vegetables was kale (Table 1). The highest infestation was observed in the last year of the study i.e. 1997, when up to 20 caterpillars were feeding simultaneously on a single plant. During 1994–1996 the highest infestation of DBM was observed in mid-July, while in 1997 it occurred in the beginning of August. The detailed information on the occurrence of DBM are presented by Jankowska (2005).

During 1994–1997, 990 pupae of DBM were collected, but only 234 moths (23.6%) were recovered from the cocoons. A part of the collected pupae (11.3%) died during rearing, due to fungal infection. The fungal diseases as a reason of mortality of DBM are recorded by Gopalakrishnan (1989) and Pell and Wilding (1994). The most important factor reducing the number of DBM was parasitization (65.1%). Results of the rearing a DBM pupae are presented in Table 2. Parasitoids were observed in each year of the study, but the parasitization varied between the years of observations and oscillated from 60% to 90.3% (Table 2).

Population dynamics of DBM and its parasitization in years presented Fig. 1 and Fig. 2. The majority of infested pupae were found in the second decade of July (1994, 1995) (Fig. 1) and the first decade of August (1997) (Fig. 2).

Table 1. The occurrence of diamondback moth (*Plutella xylostella* L.) larvae and pupae on the tested cabbage botanical varieties (Mydlniki 1993–1997)

Vegetable	Savoy cabbage	White cabbage	Blue kohlrabi	Kale	Cauli-flower	Brussel sprouts	White kohlrabi	Red cabbage	Broccoli
1994	0.28 ab	0.5 ab	0.68 c	0.13 a	0.13 a	0.8 c	0.33 ab	0.82 c	0.59 bc
1995	3.35 b	6.3 e	5.5 cde	2.05 a	4.85 cd	6.75 e	4.4 bc	5.95 de	4.53 bc
1996	0.33 a	0.91 ab	0.66 ab	0.25 a	0.73 ab	1.25 b	0.34 a	0.66 ab	0.5 ab
1997	9.14 c	11.34 d	11.33 d	13.37 e	9.47 cd	14.13 e	3.7 a	5.3 ab	6.03 b

Values followed by the same letter do not differ at 5% level of significane (Duncan's multiple test)

Table 2. Effect of rearing of larvae and pupae of diamondback moth (*Plutella xylostella* L.) collected from cabbage crops

Effect of rearing	1994		1995		1996		1997		Total	
	No.	[%]	No.	[%]	No.	[%]	No.	[%]	No.	[%]
Plutella xylostella L.	5	18.5	3	2.4	4	10.5	222	27.7	234	23.6
Parasitized larvae	18	66.7	111	90.3	36	89.5	481	60	644	65.1
Died larvae	4	14.8	9	7.3	0	0	99	12.3	112	11.3
Total	27	100	123	100	38	100	802	100	990	100

During 1994–1997, 644 specimens of parasitic wasps belonging to 11 species from families: *Ichneumonidae* (5 species), *Braconidae* (3 species), *Pteromalidae* (2 species) and *Eulophidae* (1 species) emerged from the collected DBM pupae. Species composition and numbers of parasitoids are presented in Table 3. In each year of observations *Diadegma fenestralis* Holmgr. was the most abundant species among the *Plutella* parasitoids. It constitued 71.4% of all of the wasps emerged. In the years 1994 and 1996 with low abundance of DBM, *D. fenestralis* was the only species parasitizing 66.7% and 89.5% of larvae (Tabs. 2, 3).

In Poland, in research of Łagowska (1981) *D. fenestralis* was a dominant species reducing 40–90% of pest population. Observations of *D. fenestralis* as a dominant parasitoid species were also made by Wiech and Jankowska (1999), Wiech and Kałmuk (2002, 2003). This species was observed as dominant parasitoid by Kopvillem (1959, 1960) and Moiseva (1957). It also became a natural enemy of *P. xylostella* (Devi and Raj 1995; Usha et al. 1997) in India, where it had been introduced from Europe.

The highest numbers of parasitoids were recorded in 1997 when DBM was the most abundant (Table 1), and up to 20 caterpillars were observed on individual plants. The second numerous parasitoid of *P. xylostella* caterpillars was *Diadromus collaris* Holmgr. which was obtained from 18.9% of larvae (Table 3). In Poland *D. collaris* was reported by Łagowska (1981) and Miczulski (1996). The same species was

Table 3. Species composition and quantities of parasitoid emerged from pupae of the diamondback moth (*Plutella xylostella* L.)

Family/Species	1994		1995		1996		1997		Total		Kind of parasitization
	No.	[%]	No.	[%]	No.	[%]	No.	[%]	No.	[%]	
Family *Ichneumonidae* *Diadegma semiclausum* Hellen	0	0	0	0	0	0	1	0.2	1	0.2	parasite of DBM larvae
Diadegma fenestralis Holmgr.	18	100	94	84.7	34	100	314	65.3	460	71.4	parasite of DBM larvae
Diadromus collaris Holmgr.	0	0	2	1.8	0	0	91	18.9	93	14.4	parasite of DBM pupae
Gelis nigricornis Foster	0	0	0	0	0	0	1	0.2	1	0.2	hyperparasitoid
Mesochorus spp.	0	0	2	1.8	0	0	1	0.2	3	0.5	hyperparasitoid
Family *Braconidae* *Cotesia longicauda* Wesm.	0	0	9	8.1	0	0	0	0	9	1.3	parasite of DBM larvae
Cotesia fuliginosus Wesm.	0	0	2	8.1	0	0	45	9.4	47	7.3	parasite of DBM larvae
Cotesia longipalpis Reinhard	0	0	0	0	0	0	15	3.1	15	2.3	parasite of DBM larvae
Family *Pteromalidae* *Eupteromalus* sp.	0	0	0	0	0	0	3	0.6	3	0.5	hyperparasitoid
Habrocytus sp.	0	0	1	0.9	0	0	10	2.1	11	1.7	hyperparasitoid
Family *Eulophidae* *Tetrastichus sokolowskii* Kurd.	0	0	1	0.9	0	0	0	0	1	0.2	hyperparasitoid
Total	18	100	111	100	34	100	481	100	644	100	

introduced to Asia (Ali and Karim 1995; Talekar 1996) and to New Zeland (Beck and Cameron 1990). *D. collaris* was described as larval-pupal (Avci and Ozbek 1990) or pupal (Okada 1991) parasitoid. Another ichneumonid species emerging from *P. xylostella* larvae was *Diadegma semiclausum.* Hellen. It is a common species in Great Britain and France (Rahn and Chevallerau 1996). It was introduced to Taiwan and New Zeland (Beck and Cameron 1990). In Poland it was also observed by Wiech and Kałmuk (2002, 2003).

Braconids belonging to genus *Cotesia* are considered as the most important representatives of this family reducing the number of DBM larvae (Tobias 1971; Łagowska 1981; Rice and Hahr 1994; Talekar 1996). In our experiments three species: *Cotesia longicauda* (Wesm.), *C. fuliginosus* (Wesm.) and *C. longipalpis* (Reinhard) emerged from diamondback moth pupae. Tobias (1971) and Kałmuk (2004) also observed these species as the parasitoids of DBM.

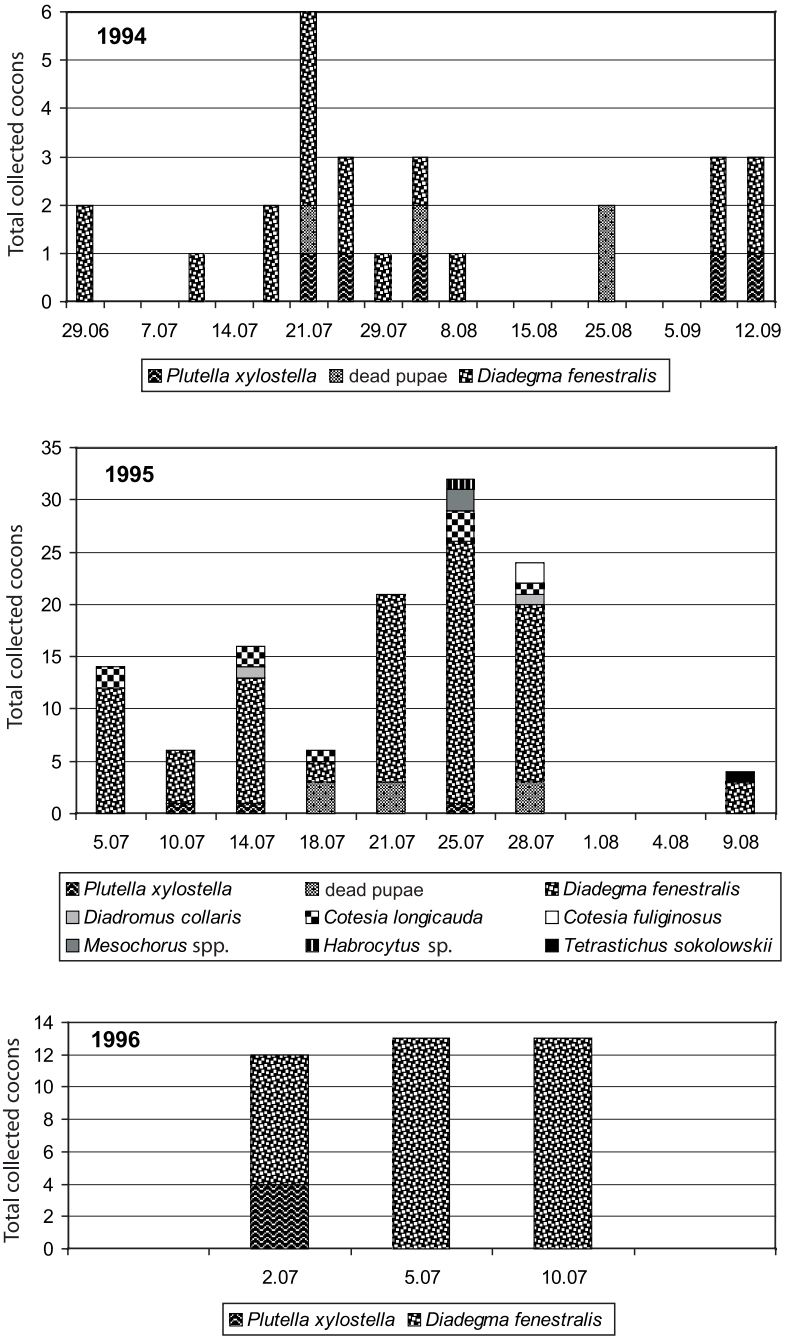

Fig. 1. Number of parasitoid adults and diamondback moths obtained from the collected cocoons in 1994, 1995 and 1996

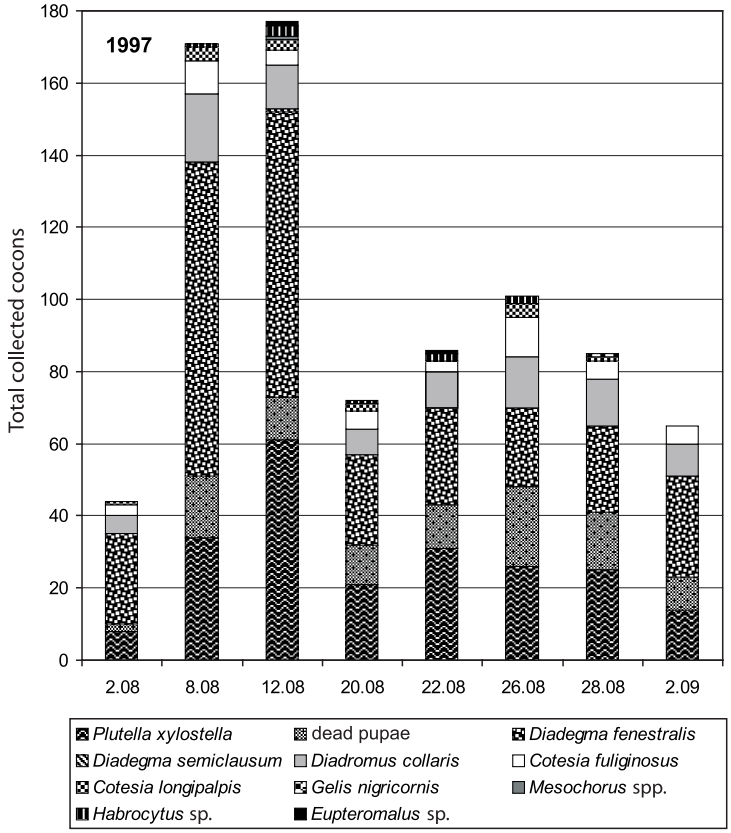

Fig. 2. Number of parasitoid adults and diamondback moths obtained from the collected cocoons in 1997

A few other wasp species occasionally paratize DBM caterpillars, but they do not have any significant effect on populations of this pest. Such species as eulophid *Tetrastichus sokolowskii* Kurd., pteromalid *Habrocytus* sp., ichneumonids *Gelis nigricornis* Foster and *Mesochorus* spp. are considered as hyperparasitoids.

In order to assess the relation between the quantity of the DBM and its parasitoids, correlation coefficients and regression coefficients were calculated. These calculations were made jointly for all vegetables and separately for each vegetable in order to evaluate the possible influence of the plant itself on this relation. It was found that the correlation is statistically significant for all vegetables under study. The regression lines show the positive relation i.e. when the amount of caterpillars increases, the amount of the parasite increases as well (Table 5). Waage (1984) in his work on the effect of caterpillars density on the parasitization by *D. fenestralis* found out that *D. fenestralis* females more often had visited plants which were artificially infested by highest number of caterpillars, but the caterpillars parasitization on this plants was not higher that on others.

In our experiments the percentage of parasitization varied between variety of vegetables, but no significant differences were noticed. The relevant data are presented in Table 4.

Table 4. Comparison of the occurrence of parasitoids of diamondback moth (*Plutella xylostella* L.) on different cabbage botanical varieties in 1994–1997

Species of parasitoids	Savoy cabbage	White cabbage	Blue kohlrabi	Kale	Cauli-flower	Brussel sprouts	White kohlrabi	Red cabbage	Broccoli
1994									
Diadegma fenestralis Holmgr.	2	4	2	0	3	3	0	1	3
Parasitization [%]	50	57	100	0	60	75	0	50	100
1995									
Diadegma fenestralis Holmgr.	4	37	8	6	4	3	6	24	2
Thyraella collaris Holmgr.	1	0	0	1	0	0	0	0	0
Mesochorus spp.	0	0	0	0	2	0	0	0	0
Cotesia fuliginosus Wesm.	0	0	0	0	0	0	0	0	2
Cotesia longicauda Wesm.	2	0	2	0	1	1	3	0	0
Habrocytus sp.	0	0	0	1	0	0	0	0	0
Tetrastichus sokolowskii Kurd.	0	0	0	0	0	1	0	0	0
Total	7	37	10	8	7	5	9	24	4
Parasitization [%]	100	97.4	100	100	87.5	35.7	90	100	100
1996									
Diadegma fenestralis Holmgr.	3	6	4	1	4	7	2	4	3
Parasitization [%]	75	85.5	100	50	100	87.5	100	100	100
1997									
Diadegma semiclausum Hellen	1	0	0	0	0	0	0	0	0
Diadegma fenestralis Holmgr.	33	49	38	70	23	63	8	18	12
Thyraella collaris Holmgr.	12	19	8	19	13	14	0	6	0
Gelis nigricornis Foster	1	0	0	0	0	0	0	0	0
Mesochorus spp.	0	0	0	0	1	0	0	0	0
Cotesia fuliginosus Wesm.	5	6	6	9	4	10	0	3	2
Cotesia longipalpis Reinhard	2	2	2	3	1	2	0	0	0
Eupteromalus sp.	0	0	0	0	1	1	0	1	0
Habrocytus sp.	0	3	0	5	1	1	0	0	3
Total	54	79	54	106	44	91	8	28	17
Parasitization [%]	58.1	63.7	58.1	65	62	62.8	40	46.7	51.5

Table 5. Corelation between the amount of diamondback moth (*Plutella xylostella* L.) and its parasitoids in 1997

Vegetable	Correlation coefficient r			Regression coefficient b	Equation of regression line
	r empiric	r theoretic p=0.05	r theoretic p=0.01		
Savoy cabbage	0.91667	0.7067	0.7887	0.541	y = 0.662 +0.541 x
White cabbage	0.93348	0.7067	0.7887	0.581	y = 0.835 +0.581 x
Blue kohlrabi	0.80574	0.7067	0.7887	0.537	y = 0.506 +0.537 x
Kale	0.99391	0.7067	0.7887	0.637	y = 0.115 +0.637 x
Cauliflower	0.9742	0.7067	0.7887	0.639	y = 0.174 +0.639 x
Brussel sprout	0.98601	0.7067	0.7887	0.721	y = 1.447 +0.721 x
White kohlrabi	0.75147	0.7067	0.7887	0.377	y = 0.106 +0.337 x
Red cabbage	0.766	0.7067	0.7887	0.263	y = 1.524 +0.263 x
Broccoli	0.91916	0.7067	0.7887	0.614	y = –0.331 +0.648 x
Total cabbage vegetables	0.9642	0.7067	0.7887	0.648	y = –4.238 +0.648 x

CONCLUSIONS

1. The parasitization oscillated from 60% to 90.3% and was very important factor reducing the number of emerging diamondback moths.
2. Eleven species belonging to families: *Ichneumonidae* (5 species), *Braconidae* (3 species), *Pteromalidae* (2 species) and *Eulophidae* (1 species) emerged from the examined pupae of DBM.
3. In each year of observations *Diadegma fenestralis* Holmgr. was the most abundant species among *Plutella xylostella* parasitoids as it constitued 71.4% of all of the emerged wasps.

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POLISH SUMMARY

SKŁAD GATUNKOWY I ROLA PARAZYTOIDÓW W OGRANICZANIU LICZEBNOŚCI TANTNISIA KRZYŻOWIACZKA (*PLUTELLA XYLOSTELLA* L.) NA RÓŻNYCH WARZYWACH KAPUSTNYCH

W latach 1994–1997 poczwarki tantnisia krzyżowiaczka (*Plutella xylostella* L.) były zbierane z dziewięciu różnych warzyw kapustowatych. Z zebranych 990 poczwarek w wyniku hodowli uzyskano tylko 23,6% motyli tantnisia krzyżowiaczka. Najważniejszym czynnikiem redukującym liczebność gąsienic było ich spasożytowanie (65,1%), które w poszczególnych latach wynosiło od 60% do 90,3%. W wyniku hodowli uzyskano 11 gatunków parazytoidów (także drugiego stopnia) należących do 4 rodzin: *Ichneumonidae* (5 gat.), *Braconidae* (3 gat.), *Pteromalidae* (2 gat.) i *Eulophidae* (1 gat.). We wszystkich latach badań największe znaczenie miał gąsienicznik *Diadegma fenestralis* Holmgr., stanowiąc 71,4% wszystkich wyhodowanych błonkówek. W latach 1994 i 1996, gdy tantniś nie występował licznie, *D. fenestralis* był jedynym występującym gatunkiem parazytoida, pasożytując 66,7% oraz 89,5% gąsienic tantnisia.