PLUTELLA XYLOSTELLA L. (LEPIDOPTERA: PLUTELLIDAE) AND ITS NATURAL BIOLOGICAL CONTROL IN THE REGION OF MOLDAVIA, ROMANIA

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Abstract. *Plutella xylostella* L. is known as a dangerous pest of cabbage cultures. The sufficiently high prolificity of its females may cause attacks with severe economic consequences. However, in Moldavia, north-eastern Romania, *P. xylostella* does not provoke important economic losses, as the growth of its populations is restricted, to a considerable extent, by the action of a complex range of parasitoid insects, which attain parasitoid ratios over 60-70%, sometimes exceeding 90%. For more than 30 years, the authors followed the evolution of the parasitoid species capable of controlling the *P. xylostella* populations of Moldavia, signaling the presence of a complex of over 30 parasitoid species, the conjugated actions of which maintain the populations of this pest under the economic threshold of damage. Thus, in the conditions of Moldavia, *P. xylostella* is under a natural biological control.

Keywords: cabbage, damage, parasitoids, hyperparasitoids, parasitoid biocoenosis, biological control.

Rezumat. *Plutella xylostella* L. (Lepidoptera: Plutellidae) aflată sub control biologic natural în condiţiile din Moldova, România. *Plutella xylostella* L. este un dăunător periculos al culturilor de varză. Prolificitatea destul de mare a femelelor poate determina apariţia unor atacuri cu consecinţe economice grave. Totuşi, în Moldova, *Plutella xylostella* L. nu provoacă pagube economice mari, deoarece populaţiile sunt limitate în mare măsură, ca urmare a acţiunii unui complex de insecte parazitoide, care realizează procentaje de parazitare de peste 60-70%, uneori depăşind 90%. De mai bine de 30 de ani am urmărit speciile parazitoide care limitează populaţiile de *P. xylostella* L. în Moldova şi am semnalat prezenţa unui complex de peste 30 de specii parazitoide care îşi conjugă acţiunile şi menţin populaţiile acestui dăunător sub pragul economic de dăunare. Deci, în condiţiile din Moldova *P. xylostella* se află sub control biologic natural.

Cuvinte cheie: varză, pagube, parazitoizi, hiperparazitoizi, biocenoze parazitoide, control biologic.

Introduction

Plutella xylostella attacks cultures of cabbage, cauliflowers and any other wild or cultivated Cruciferae. In Romania, it produces three generations in the southern regions and two generations in the northern ones, so that, comparatively with South-Eastern Asia, where up to 20 generations occur yearly (as they multiply similarly with the aphids) one may say that, in Romania, this species considerably less damaging.

During the investigations performed in more than 60 Moldavian localities, a complex of over 25 species of primary parasitoids, attaining high parasitation ratios (60-70%, sometimes exceeding even 90%), has been identified in several cultures, the *P. xylostella* populations remaining under the threshold of damage (Constantineanu & Mustaţă, 1972, 1973; Mustaţă & Lăcătuşu, 1973; Mustaţă & Tudor, 1973; Mustaţă, 1979, 2001; Mustaţă & Costea, 2000; Mustaţă & Mustaţă, 2000).

Nevertheless, in the last decade, the number of secondary parasitoids active within the populations of this pest has increased, which limits the beneficial effect induced by the primary parasitoids. The present study analyses the evolution of the parasitoid complex from the *P. xylostella* populations over a period of almost four decades, which allows a better understanding and evolution of the phenomenon, developed in such parasitoid type biocoenoses.

Materials and Methods

Over the more than three decade period dedicated to the analysis of the parasitoid complex known as limiting the *P. xylostella* populations, both larvae and pupae from cabbage cultures have been collected from more 60 Moldavian localities. They have been brought in the laboratory, where they produced *P. xylostella* and parasitoid adults. The trophic relations developed among the species have been carefully examined, analyses being sometimes made on the remains left by the parasitoid species, after adults' hatching. To elucidate the control exercised by the parasitoid species of the *P. xylostella* populations, analyses have been performed over three distinct periods of time 1967-1970, 1990 and 2004), the material under study having provided important information on the number of parasitoid species which together, contribute to the limitation of the *P. xylostella*, on the limiting ratios attained, as well as on the intervention of the secondary parasitoids. For a correct understanding of the position of the parasitoid species and of the contribution they bring to restricting the *P. xylostella* populations, a synecological analysis of the parasitoid species was developed, in parallel with the settlement of trophic network characteristic to this type of biocoenosis.

Results and Discussion

The first investigations devoted to *P. xylostella* have been initiated as early as 1967, when mature larvae and pupae had been collected and followed in laboratory conditions. Some hints on the natural biological control of the *P. xylostella* populations of Moldavia challenged the authors to re-consider the data gathered in the years 1967-1970, 1990 and 2004, some new aspects found out being already published (Mustaţă, 1973, 1992; Mustaţă *et al.*, 2002).

In the material collected and processed between 1967-1970, out of the 4783 collected hosts, 1268 butterflies and 3495 primary parasitoid hatched, which means a parasition degree of 73.77% was recorded in Roman, on May 31, 1969, while the lowest one (27.59%) at Valea Lupului, Iaşi, on July 19, 1970 (Fig. 2).

The primary parasitoids identified during the study belong to 19 species (Table 1); also, 3 species of secondary parasitoids were discovered.

Mesochorus vittator Zett. obtained from *Diadegma fenestrale* Holmgr. (11 individuals) and *D. .armillatum* Grav., (9 individuals).

Lysibis vsritarsus Grav.from *D. fenestrale* and *D .armillatum* (14 individuals).

Dibrachys cavus Walk. from *D. armillatum* and *D. chrysostictos* Grav. (21 individuals).

In the year 1990, a number of 18147 larvae and pupae of *P. xylostella* have been collected, of which 5345 butterflies and 12805 parasitoids hatched, which represents a parasitation degree of 70.56%. The highest value of this parameter (95.43%) was registred at Racaciuni – Bacau, on August 15, 1990, while the lowest one (33.20%) at Podu Iloaiei – Iasi, on August, 26, 1990. The primary parasitoids under analysis belong to 20 species (Table 2, Fig. 3). In their turn, part of the primary parasitoids has been attacked by some species of secondary parasitoids, as follows:

Mesochorus facialis Bridgm. was obtained from *Apanteles rubripes* Holiday;

Mesochorus anomalus Holmgr. was obtained from *Apanteles rubripes* Holiday;

Mesochorus orbitalis Holmgr. was obtained from *Cotesia plutellae* Kurdj., and *C.rubecula* Marsh.;

Lysibia varitarsus was obtained from *D. fenestrale*, *D. armillatum* and *D. chrysostictos*

The samples collected in 2004 amounted to 4034 *P. xylostella* larvae and pupae, of which 1119 butterflies and 2915 primary parasitoids belonging to 21 species (Table 3, Fig. 4) hatched.

Table 1. The synecological analysis of the parasitoid species in the conditions of the years 1967-1970.

No.	Species	Abundance	Constancy		Dominance		Ecological significance index	
1.	*Diadegma fenestrale*	489	100	C_4	13.99	D_5	13.99	W_5
2.	*Diadegma chrysostictos*	486	100	C_4	13.90	D_5	13.90	W_5
3.	*Diadegma semiclausum*	473	100	C_4	13.53	D_5	13.53	W_5
4.	*Diadegma armillatum*	389	100	C_4	11.13	D_5	11.13	W_5
5.	*Diadegma trochanteratum*	359	100	C_4	10.27	D_5	10.27	W_5
6.	*Diadegma holopyga*	289	100	C_4	8.26	D_4	8.26	W_4
7.	*Diadromus subtilicornis*	158	89	C_4	4.52	D_3	4.02	W_3
8.	*Diadromus collaris*	143	79	C_4	4.09	D_3	3.23	W_3
9.	*Diadromus ustulatus*	142	76	C_4	4.06	D_3	3.08	W_3
10.	*Itoplectis alternans*	137	81	C_4	3.91	D_3	3.16	W_3
11.	*Diadegma gibbula*	81	65	C_3	2.31	D_3	1.50	W_2
12.	*Apanteles fuliginosus*	62	53	C_3	1.77	D_2	0.93	W_2
13.	*Apanteles ruficrus*	43	51	C_3	1.23	D_2	0.62	W_2
14.	*Itoplectus tunetanus*	31	49	C_2	0.88	D_1	0.43	W_2
15.	*Hyposoter ebeninus*	21	36	C_2	0.60	D_1	0.21	W_2
16.	*Itoplectis viduata*	21	42	C_2	0.60	D_1	0.25	W_2
17.	*Dicaelatus parvulus*	16	25	C_1	0.45	D_1	0.11	W_2
18.	*Cotesia rubecula*	7	14	C_1	0.20	D_1	0.02	W_1
19.	*Diadegma interrupta*	6	8	C_1	0.17	D_1	0.01	W_1
	Total	3495						

The parasitation degree was 72.26%, the most significant reduction of the *P. xylostella* populations (94.43%) at Faraoani – Bacău, in the same day.

In their turn, a considerable number of primary parasitoids have been attacked by secondary parasitoids.

Lysibia varitarsus was obtained from *D. semiclausum* (Helen) (11 individuals) and *D. fenestrale* (9 individuals);

Stictopisthus bilineatus Thoms. was obtained from *Cotesia rubecula* (3 individuals);

Mesochorus vittator was obtained from *D. semiclausum* (21 individuals), *D. fenestrale* (14 individuals) and *D. armillatum* (18 individuals);

Mesochorus facialis was obtained from *D. semiclausum* (15 individuals) and *D. fenestrale* (11 individuals);

Catolaccus ater Ratz. was obtained from *Diadegma semiclausum* (from 95 hosts) and *Cotesia plutellae* (from 11 hosts) and *Apanteles appelator*Tel. (from 4 hosts);

Dibrachys cavus Walker was obtained from *D. semiclausum* (from 18 hosts) and *D . fenestrale* (from 51 hosts);

Pteromalus semotum Walker was obtained from *D. fenestrale* (from 32 hosts), *D. semiclausum* (from 21 hosts) and *Cotesia plutellae* (from 14 hosts);

Trichomalopsis peregrina (Graham) was obtained from *D. armillatum* (from 4 hosts);

Oomyzus sokolovskii Kurdj. was obtained from *Cotesia plutellae* (from 13 hosts) and *Apanteles appelator* (from 5 hosts).

Analysis of the parasitoid species active in the *P. xylostella* populations has evidenced an impressive number of primary and secondary parasitoids.

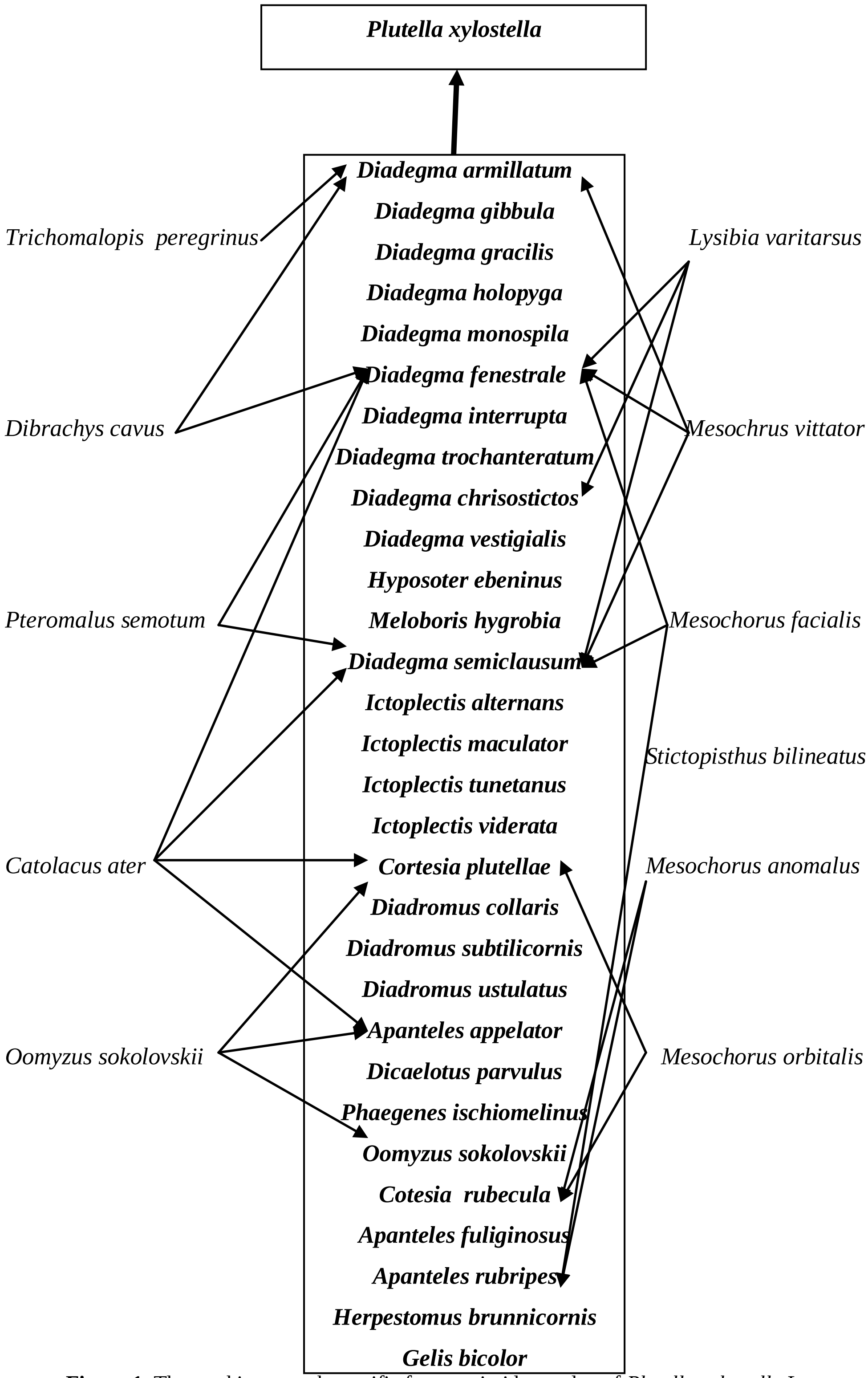

Figure 1. The trophic network specific for parasitoid complex of *Plutella xylostella* L.

Primary parasitoids:

The Ichneumonidae family: 1. *Diadegma armillatum* Grav., 2. *D. chrysostictos* Grav., 3. *D. fenestrale* Holmgr., 4. *D. gibbula* Brisch., 5. *D. gracilis* Grav., 6. *D, holopyga* Thoms., 7. *D. interrupta* Holmgr., 8. *D. monospila* Thoms., 9. *D. semiclausum* (Hellen), 10. *D. trochanteratum* Thoms,. 11. *D. vestigialis* Rtzbg., 12. *Hyposoter ebeninus* Grav., 13. *Meloboris hygrobius* Thoms., 14. *Itoplectus alternans* Grav., 15. *I. maculator* F., 16. *I. tunetanus* Schm., 17. *I. viduata* Grav., 18. *Diadromus collaris* Brisch., 19. *D. subtilocornis* Grav., 20. *D. ustulatus* Holmgr., 21. *Dicaelotus parvulus* Grav., 22. *Phaeogenes ischiomelinus* Grav., 23. *Herpestomus brunnicornis* Grav., 24. *Gelis bicolor* Grav.

The Braconidae family: 25. *Apanteles appelator* Tel., 26. *A. fuliginosus* Wesm., 27. *A. rubripes* Holiday, 28. *Cotesia plutellae* Kurdj. , 29. *C. rubripes* Holiday.

The Eulophidae family: 30. *Oomyzus sokolovskii* Kurdj.

Secondary parasitoids:

The Ichneumonidae family: 1. *Lysibia varitarsus* Grav., 2. *Mesochorus anomalus* Holmgr., 3. *M. facialis* Bridgm., 4. *M. orbitalis* Holmgr., 5. *M. vittator* Zett., 6. *Stictopisthus bilineatus* Thoms.

The Pteromalidae family: 7. *Catolaccus ater* Ratz., 8. *Dibracys cavus* Walker, 9. *Pteromalus semotus* Walker, 10. *Trichomalopsis peregrina* (Graham).

The Eulophidae family: 11. *Oomyzus sokolovskii* Kurdj.

To elucidate the trophic relation developed between the species of this biocoenotic complex, a trophic network has been created (Fig. 1). Thus, it has been observed that, in recent years, the parasitism degree of certain primary parasitoids is quite high, as follow: *Diadegma armillatum* 6.85%, *D. fenestrale* 16.38%, *D. semiclausum* 21.16%, *Cotesia plutellae* 40.86% and *Apanteles appelator* 50%.

Apparently, such a situation is quite alarming, if not for the *Apanteles appelator* species, an accessory and receding one characterized by a quite low abundancy, but certainly dangerous for the *Diadegama armillatum*. *D. fenestrale* and *D. semiclausum* species, eudominant and euconstant ones, possessing a maximum index of ecological significance (W5).

If, out of 855 *D. semiclausum* individuals, 181 were parasitated, which means a ratio of 21.16%, then the situation appears, indeed as upsetting.

Cotesia plutellae, which is not a new species for Romania, although it seems as being not very old here, has discovered quite late. In spite of this, the ratio in which it is -parasited is surprisingly high. *C. plutellae* appears as a subdominant and constant species, with a sufficiently high indes of ecological significance.

The synecological analysis of the parasitoid species evidences that, between 1967-1970, no less than 10 species are euconstant in the *P. xylostella* populations, while other 3 are constant, 3 accessory and 3 accidental. Five species, i.e. *D. armillatum*, *D .fenestrale*, *D. semiclausum*, *D. chrysostictos* and *D .trochanteratum* are euconstant, evidencing the maximum index of ecological significance W5) (Table 1, Fig. 2).

In 1990, there appear 7 euconstant species, 2 constant, 3 accessory and 8 accidental. *D. armillatum*, *D. fenestrale*, *D. chrysostictos* and *Diadromus subtilicornis* and *D. ustulatus* are eudominant, with an index of ecological significance W5, while *D. semiclausum*, *Diadromus collaris* and *D. ustulatus* are dominant (Table 2, Fig. 3).

In the year 2004, 7 euconstant and 6 constant species, 2 accessory and 5 accidental ones were found (Table 3, Fig. 4). *D. semiclausum*, *D. fenestrale* and *D. armillatum* are euconstant, with a maximum value of their index of ecological significance.

Especially important is the fact that the eudominant and dominant, euconstant and constant species remained present the populations along the almost 40 years period under analysis. It goes without saying that, in spite of some natural overturns of dominancy, from one period to another and from one culture to another, the euconstant and constant species manifested their uninterrupted presence in the population of this pest, and also that, together with the accessory and accidental species, conjugate their actions towards limitation of pest populations.

Table 2. The synecological analysis of the parasitoid species in the conditions of the year 1990.

No.	Species	Abundance	Constancy		Dominance		Ecological significance index	
1.	*Diadegma fenestrale*	3082	100	C_4	24.06	D_5	24.06	W_5
2.	*Diadegma armillatum*	2173	100	C_4	16.96	D_5	16.96	W_5
3.	*Diadegma chrysostictos*	1735	100	C_4	13.54	D_5	13.54	W_5
4.	*Diadromus subtilicornis*	1702	100	C_4	13.29	D_5	13.29	W_5
5.	*Diadegma semiclausum*	1203	100	C_4	9.39	D_4	9.39	W_4
6.	*Diadromus collaris*	938	76	C_4	7.32	D_4	5.56	W_4
7.	*Diadromus ustulatus*	705	81	C_4	5.50	D_4	4.45	W_3
8.	*Diadegma trochanteratum*	411	66	C_3	3.20	D_3	2.11	W_3
9.	*Diadegma crassum*	302	52	C_3	2.35	D_3	1.22	W_3
10.	*Diadegma gibbula*	196	35	C_2	1.53	D_2	0.53	W_2
11.	*Diadegma holopyga*	109	28	C_2	0.85	D_1	0.23	W_2
12.	*Itoplectis alternans*	75	31	C_2	0.58	D_1	0.17	W_2
13.	*Phaeogenes ischiomelinus*	56	22	C_1	0.43	D_1	0.09	W_1
14.	*Dicaelotus parvulus*	37	18	C_1	0.28	D_1	0.05	W_1
15.	*Itoplectus viduata*	25	21	C_1	0.19	D_1	0.03	W_1
16.	*Hyposoter ebeninus*	20	12	C_1	0.15	D_1	0.01	W_1
17.	*Apanteles ruficrus*	18	14	C_1	0.14	D_1	0.019	W_1
18.	*Apanteles rubecula*	11	8	C_1	0.08	D_1	0.006	W_1
19.	*Apanteles fuliginosus*	5	2	C_1	0.03	D_1	0.0006	W_1
20.	*Herpestomus brunnicornis*	1	1	C_1	0.007	D_1	0.0001	W_1
	Total	12.805						

Table 3. The synecological analysis of the parasitoid species in the conditions of the year 2004.

No.	Species	Abundance	Constancy		Dominance		Ecological significance index	
1.	*Diadegma semiclausum*	855	100	C_4	29.33	D_5	29.33	W_5
2.	*Diadegma fenestrale*	714	100	C_4	24.49	D_5	24.49	W_5
3.	*Diadegma armilatum*	321	100	C_4	11.01	D_5	11.01	W_5
4.	*Diadegma chrysostictos*	189	92	C_4	6.48	D_4	5.96	W_4
5.	*Diadromus subtilicornis*	177	76	C_4	6.07	D_4	4.61	W_3
6.	*Diadegma trochanteratum*	152	84	C_4	5.21	D_4	4.37	W_3
7.	*Diadromus collaris*	119	88	C_3	4.08	D_3	3.59	W_3
8.	*Cotesia plutellae*	93	79	C_3	3.19	D_3	2.52	W_3
9.	*Diadegma holopyga*	71	75	C_3	2.43	D_3	1.82	W_3
10.	*Diadromus ustulatus*	63	78	C_4	2.16	D_3	1.68	W_3
11.	*Itoplectus alternans*	56	65	C_3	1.92	D_2	1.24	W_3
12.	*Diadegma crassum*	31	59	C_3	1.06	D_2	0.62	W_2
13.	*Apanteles rubecula*	22	55	C_3	0.75	D_1	0.41	W_2
14.	*Apanteles appelator*	18	34	C_2	0.68	D_1	0.23	W_2
15.	*Hyposoter ebeninus*	11	23	C_2	0.37	D_1	0.08	W_1
16.	*Phaeogenes ischiomelinus*	8	18	C_1	0.27	D_1	0.04	W_1
17.	*Itoplectus maculator*	6	12	C_1	0.20	D_1	0.02	W_1
18.	*Apanteles rubripes*	6	12	C_1	0.20	D_1	0.02	W_1
19.	*Herpestomus brunnicornis*	2	2	C_1	0.06	D_1	0.0012	W_1
20.	*Gelis bicolor*	1	1	C_1	0.03	D_1	0.0006	W_1
	Total	2.915						

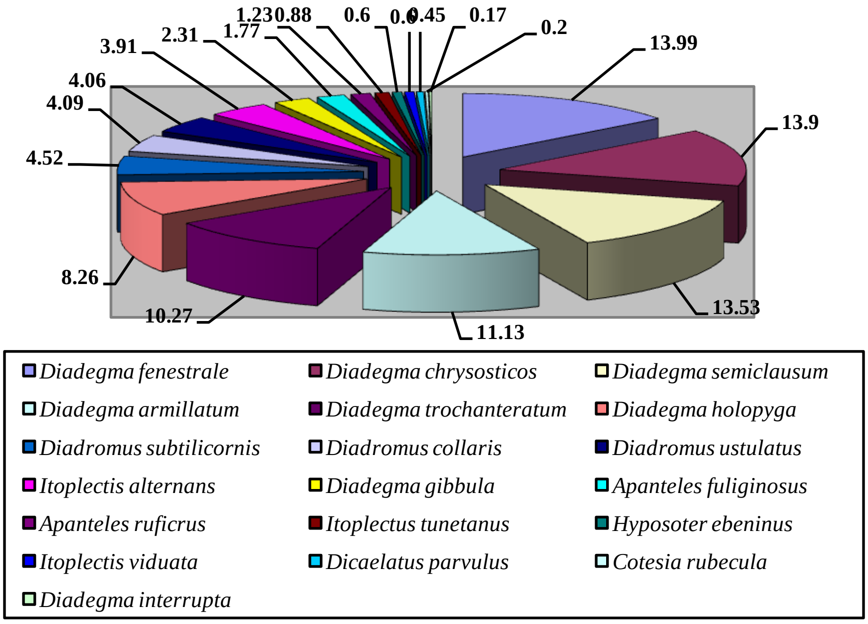

Figure 2. Procentages of parasitoid species in *Plutella xylostella* L. populations in 1967-1970 period.

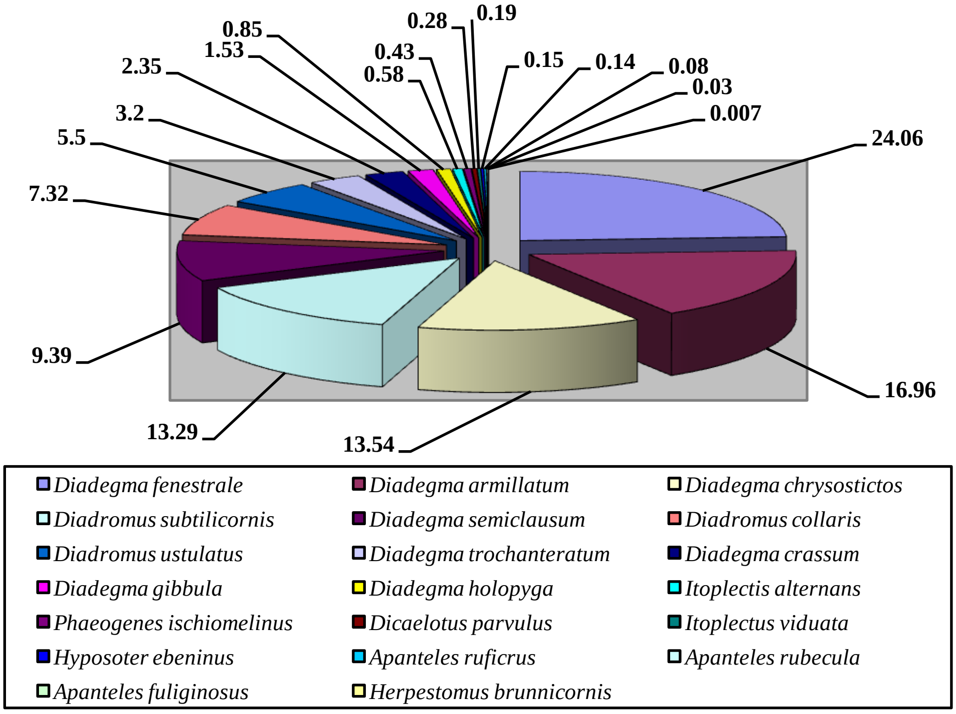

Figure 3. Procentages of parasitoid species in *Plutella xylostella* L. populations in 1990.

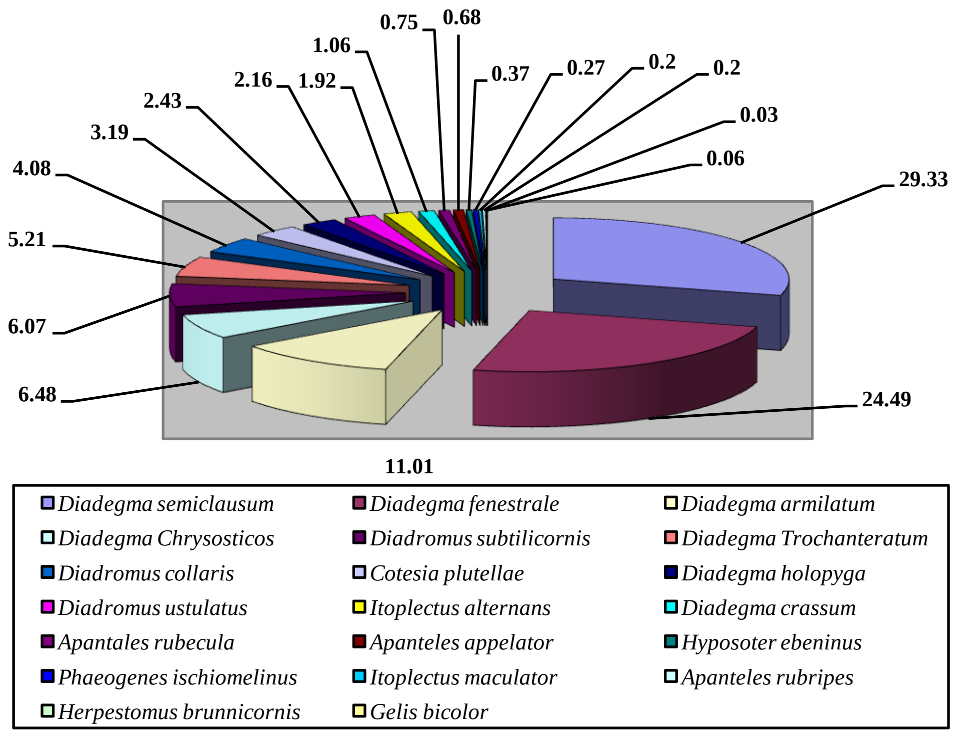

Figure 4. Procentages of parasitoid species in *Plutella xylostella* L. population in 2004.

Special mention should be made once again here of the increase in the number of secondary parasitoids from one period to another, and also of their increased efficiency in restricting some primary parasitoids.

Another important observation refers to the fact, in the control of *P. xylostella*, no parasitoid insects grown in laboratory conditions have been utilized. The parasitoid complexes under discussion belong to the fauna of Moldavia, while their action is strictly natural.

The presence and, especially the growth in the number of secondary parasitoids are equal astonishing and perplexing. The action of primary parasitoids, as part of the concept of natural equilibrium, is advantageous to human economy. Man, dividing animals into adverse categories, i.e., useful and detrimental, is obviously interested in restricting the action of the latter ones. The natural mechanism is assured by the intervention of the entomophagous (predatory and parasitoid) animals what happens, however, when hyperparasitoids insects intervene within the biocoenosis? Is their intervention useful or damaging? Of course, from an economical perspective, secondary parasitoids appear as damaging organisms. The notion of hyperparasitoids should include not only secondary, but also tertiary and quaternary parasitoids. Such complexes of parasitoids are present everywhere, predominantly in aphid colonies. In the economy of nature, the past played by secondary parasitoids seems beneficial, once they assure the occurrence of the (so called damaging) phytophagous organisms at a certain level (under the threshold of economic damages), and not their complete elimination. Also, the role of tertiary parasitoids at the level of biocoenosis appears, too, as beneficial, as they restrict the intervention of secondary parasitoids and favorized the primary parasitoids in their action, which is advantageous for man. An especially interesting aspect is the following:

most of the tertiary parasitoids may also act as secondary, and even as quaternary parasitoids, which is actually a function of the biomass they are oppered. In such case, tertiary parasitoids act as a genuine buffer system in the biocoenosis, impeding the exponential development of some species. Such a buffer system plays an extremely important part assuring natural equilibrium.

In the natural limitation of the *P. xylostella* populations, primary parasitoids have been a beneficial action, restricting, in a decisive manner, (i.e., up to 80-90 %) the *P. xylostella* populations. In such situations, the intervention of the secondary parasitoids appears natural, although their action is a disturbing one. Equally natural is that, if the situation remains unchanged, i.e., if the number of secondary parasitoids increases, their effect increases to the same extinct, so that, shortly, the intervention of the tertiary parasitoids is manifested. This seems to be the best way to follow in the realization of some parasitoid biocoenosis for attainment of their climax condition.

Mention should be also made of the fact that, in South-East Asia, the number of generations of the *P. xylostella* species is impressive, indeed. Thus, in Taiwan, up to 15-20 generations appear each year, as they multiply in a similar manner with the aphids. In the case of aphids, parasitoid biocoenoses are characterized by a very high number of parasitoid species of various grades (primary, secondary, tertiary and even quaternary parasitoids). A similar situation should be expected in the *P. xylostella* populations, too, yet not in South-East Asia, because, in this region, *P. xylostella* migrates, being not followed by the whole group of parasitoids. In this case, *P. xylostella* behaves like the *Leptinotarsa decemlineata* species does in Europe. This species arrived in Europe alone, without being accompanied by the entomophagous complex capable of controlling its populations.

All these considerations support the conclusions of other studies of course, namely that the more controlled is phytophagous species by several natural enemies, the closer is it to its worldwide genetic center. It seems that, in Central Europe, *P. xylostella* is controlled by the highest possible number of entomophagous organisms, which means that its worldwide genetic center is Central Europe.

Conclusions

In the environmental conditions of Moldavia, *Plutella xylostella* L. is controlled by a powerful complex of parasitoid insects which, in most cases, maintain its populations under the economic threshold of damage. The parasitism degree exceeds 60-70, sometimes arriving up to 90%. More than 25 species of parasitoid insects conjugate their parasitism actions for restricting the *P. xylostella* populations.

In the last two decades, a very interesting aspect has been observed, namely the increased number of secondary parasitoid species and, consequently, even their efficiency in the limitation of some primary parasitoids.

The study attempts at finding the causes of such phenomenon by a correct and through presentation of the state of the art. The presence of such a large number of primary parasitoids in the *P. xylostella* populations of Moldavia might be a proof of the fact that the worldwide genetic center of this species occurs in this very part of Europe. Also, the massive presence of secondary parasitoids and their remarkable efficiency support, on the side, this hypothesis while, on the other, it evidences that such a type of parasitoid biocoenosis gets closer to its climax.

Involved here being not a controlled biological combat but a natural mechanism of regulating the number of individuals within some interdependent species, the key factors through which natural equilibrium is attained, impeding the exponential development of some species, in parallels with the estimation of others, are fully manifested.

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