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Population dynamics of *Plutella xylostella* (Lep., Yponomeutidae) and its parasitoids in the region of Brasilia

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Abstract: The diamond back moth *Plutella xylostella* (L.) is the most serious pest of Brassicaceae in the world. It is resistant to many insecticides which has led to a search for alternative techniques of control, principally biocontrol-based pest management. The impact of *P. xylostella* and its parasitoids was analysed in a 6-month study of cabbage crops in the Brasilia region of Brazil, from June to November 1998. The population of the pest and its guild of parasitoids were quantified on two experimental plots at the Embrapa-Hortaliças research station by weekly samplings. In the first cropping (June to early September), populations of *P. xylostella* followed a logistic growth curve leading to the destruction of the crops. In the second cropping, rains prevented the development of *P. xylostella*. Seven species of parasitoids were observed, *Diadegma leontiniae* (Brethes) and *Apanteles piceotrichosus* (Blanchard) being dominant. *Cotesia plutellae* (Kurdjumov) and *Actia* sp., previously more abundant, became very minor parasitoids. Significant differences were observed in specific parasitism rates between the plots. The combined parasitism rates were identical on both plots (around 23%) and were insufficient to regulate the populations of *P. xylostella*. Six species of hyperparasites were reared from *Diadegma leontiniae* and *Apanteles piceotrichosus*, showing a high diversity of natural enemies in this region of recent colonization by *P. xylostella*.

Key words: *Plutella xylostella*, biological control, cabbage, insecticide resistance, parasitoids

1 Introduction

The diamond back moth, *Plutella xylostella* (Linnaeus) (Lep., Yponomeutidae) is the most destructive Brassicaceae crop pest in the world. The cost of control measures worldwide is approximately one billion $US annually (Talekar and Shelton, 1993). The emergence of insecticide resistant populations has driven current research towards the development of alternative methods for control of this pest and particularly natural pest control (Tabashnik and Cushing, 1987). This paper focuses on the status of *P. xylostella* and its natural enemies in Brasilia where cabbages are a major food crop and insecticides are inefficient for control (Castelo-Branco and Gatehouse, 1997).

2 Materials and methods

Two 500-m^2 plots containing 1000 heads of cabbage each (variety hybrid 'Kenzan') were planted in experimental fields at the Embrapa-Hortaliças research station (30 km south-west of Brasilia), from June to November 1998, with two successive croppings. These plantations were grown without applying manure and pesticides, in order to not interfere with the development of the *P. xylostella* parasitoids. The first field (plot 1) is near a river and is sheltered by a nearby forest. Plot 2, 2 km east of plot 1, is surrounded by other cultivated fields and is more exposed to the wind. Thermohygrographs permanently registered the temperature and humidity in the fields and a weather station midway between the two fields provided more information on other weather-related factors i.e. precipitation, wind, evapotranspiration and light intensity.

The climate in Brasilia (altitude 1150 m) is typical of a 'cerrados' or tropical savannah (Ratter et al., 1997): a hot, wet season occurs from October to March with average temperatures of about 22–23°C and rainfall of about 1000 mm and a slightly cooler dry season from April to September when average temperatures oscillate around 20–22°C and rainfall is only 150 mm (NOAA, 1998).

Every week, 20 cabbage heads were randomly picked and then decorticated to collect the insects that were present. With the exception of first instar larvae which mine the leaves, insects from each sample were separated by larval instar (second, third and fourth instars) and reared until either the adult moth stage or a parasitoid was obtained. Larvae were reared in square aerated plastic boxes (30 × 30 × 10 cm), with a maximum of 100 larvae in each box. Larvae were fed with fresh cabbage leaves, collected from an organic cabbage culture near Brasilia and carefully washed in order to eliminate potential pathogens and unsolicited *P. xylostella* eggs and larvae. The *P. xylostella* pupae were kept in smaller boxes. The parasitoid cocoons were collected from the field, retained and observed for the presence of hyperparasites. These cocoons and parasitized *P. xylostella* pupae (recognizable by the colour, or later by longer developmental duration) were kept individually in gelatine capsules. The mean number of individuals emerging from a single attacked host in gregarious parasitoid species was recorded. All rearing was carried out at room temperature (21 ± 2°C).

The feeding preferences of certain species of larval parasitoids (i.e. their preference for certain larval stages of *P. xylostella*) could be determined using a log-linear model (SAS Genmod procedure) (McCullagh and Nelder, 1989).

3 Results

3.1 The pest

The *P. xylostella* populations followed an identical growth curve in both plots. The cumulative growth curves for the two populations were analysed by Students *t*-test which showed no significant difference between the two plots ($t = 2.12$ – NS – d.f. = 14). The two populations evolved in the same fashion and were subjected to the same influences. In the first crop, an exponential growth phase was observed from the second to the ninth week with the *P. xylostella* population growing from 0 to 2200 individuals (for the 20 cabbages of the sampling) for plot 1 (fig. 1) and from the fourth to the 11th week for plot 2 where the population grew from 20 to 1850 individuals. This is approximatively equivalent to a doubling of the individuals harvested each week. The population in the second cabbage crop stayed low and was never more than 15 individuals per week (on the 20 cabbages).

Other pests such as *Spodoptera frugiperda* (Fabricius) and *Trichoplusia ni* (Hübner) (Lep., Noctuidae) were occasionally observed. *Hellula undalis* (Linnaeus) (Lep., Pyralidae) whose larvae drill into the stems and central meristem of young cabbage were also found. No parasitoids were harvested from these secondary pests.

3.2 Natural enemies

The natural enemies of *P. xylostella* observed in this study were largely larval endoparasitoids with the exception of *Oomyzus sokolowskii* (Kurjumov) (Hym., Eulophidae), a larval–nymphal parasite, and two *Conura* spp., pupal parasitoids (table 1). The mean global parasitism rate from first to last sampling week on the first crop was 23.5% (24.5 and 22.6% in plots 1 and 2, respectively).

Diadegma leontiniae (Hym., Ichneumonidae), the most commonly found species in the larvae of *P. xylostella* throughout South America, was present on 65% of the parasitized caterpillars found.

A significantly different increase in parasitism level from *P. xylostella* stage L2 to stage L3 ($P < 0.0001$), and from stage L3 to stage L4 ($P < 0.0001$) was observed for *D. leontiniae*.

The second most common species was *Apanteles piceotrichosus* (Blanchard) (Hym., Braconidae) (20.6%), already reported in the south of Brazil in the state of Rio Grande do Sul (Ferronatto and Becker, 1984). *Apanteles piceotrichosus* showed no significant increase in its level of parasitism for any particular stage. The hyperparasites found in the *Apanteles* cocoons suggest that it could belong to the allied genus *Dolichogeneidea* (G. Delvare, pers. comm.).

The third most commonly found species was *Oomyzus* (*Tetrastichus*) *sokolowskii*. This was reported for the first time in South America by Ferronatto and Becker (1984). An average of 8.3 individuals emerged from each parasitized pupa ($n = 301$ pupae).

The above three species represent 99% of the parasitoids found in this population of *P. xylostella*. Only a dozen *Cotesia plutellae* (Kurdjumov) (Hym., Braconidae) were found, although this had been very

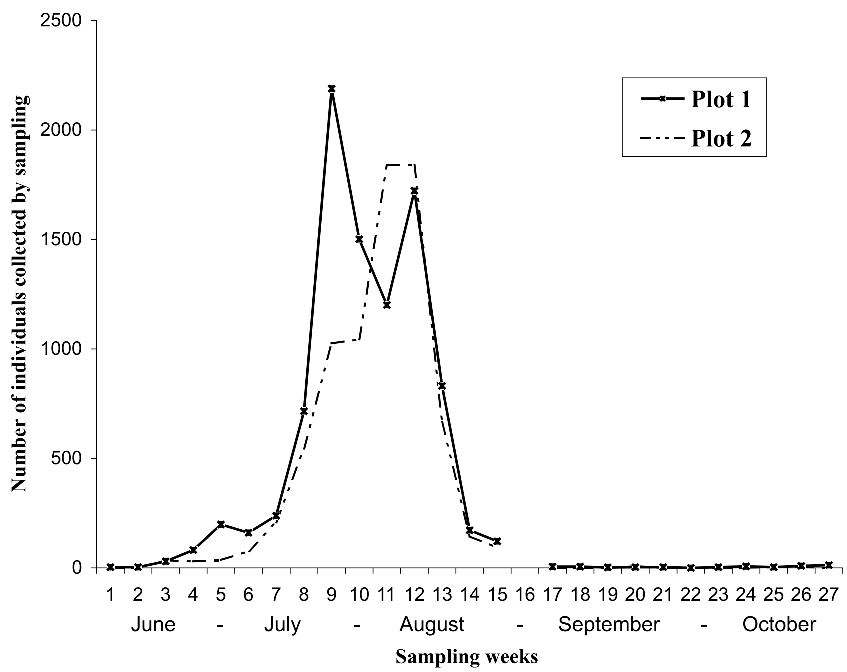

Fig. 1. *Plutella xylostella population build up in the plots at Embrapa-Hortaliças (Brazil)*

Table 1. *Parasitoids reared from* Plutella xylostella *populations in plots 1 and 2 (n = 3333 individuals)*

Species	Percentage
Diadegma leontiniae Brethes (Hym., Ichneumonidae)	64.6
Apanteles piceotrichosus Blanchard (Hym., Braconidae)	20.6
Oomyzus sokolowskii (Kurdjumov) (Hym., Eulophidae)	13.9
Cotesia plutellae (Kurdjumov) (Hym., Ichneumonidae)	0.36
Conura (= *Spilochalcis*) *pseudofulvovariegata* (Becker) (Hym., Chalcididae)	0.30
Actia sp. (Dipt., Tachinidae)	0.24
Conura (= *Spilochalcis*) near *unimaculata* (Ashmead) (Hym., Chalcididae)	0.03

The percentage values are the proportion of each species in total parasitism.

abundant during the previous years (Barbosa and França, 1981; Monnerat, 1995). Only eight *Actia* sp. (Dipt., Tachinidae), were collected in the first crop although this was also previously reported as being an abundant species, especially at the end of the dry season (M. Castelo-Branco, pers. comm.). Ten specimens of *Conura pseudofulvovariegata* (Becker) (Hym., Chalcididae) were found as occasional hyperparasites of *D. leontiniae*. It should be noted that *Conura* was only recently placed in this genus, having been previously placed in *Spilochalcis* (G. Delvare, pers. comm.). *Conura pseudofulvovariegata* was recently found in Brazil as a secondary parasitoid (Becker, 1989). Only a single *Conura* near *unimaculata* was collected from a *Plutella* pupa.

3.3 The hyperparasites

A small number of hyperparasites were collected from *D. leontiniae* cocoons (table 2). *Basileucus* sp. (Hym., Ichneumonidae) and *Haltichella* sp. (Hym., Chalcididae) were only found as males (three and five respectively) and were not identifiable at the species level. Only one attack by *Trichospilus diatreae* (Cherian and Margabandha) (Hym., Eulophidae) was observed (this is a gregarious parasitoid).

The hyperparasites come from a number of different species but the total number of attacks was fairly low, reaching a mean rate of 3.3 and 3.4% for *Apanteles* and *Diadegma*, respectively. *Apanteles piceotrichosus* was attacked by three different hyperparasites, these being *Haltichella* sp. (61%), *Trichomalopsis oryzae* (Risbec) (Hym., Pteromalidae) (26%) and *C. pseudofulvovariegata* (13%), in the order of abundance.

Diadegma leontiniae was attacked by six different species: *C. pseudofulvovariegata* (58%); *Aphagnomus fijiensis* (Ferrière) (Hym., Ceraphronidae) (23%), a gregarious species; *Haltichella* sp. (6.5%) and three other species accounting for < 5% each: *Basileucus* sp., *Brachymeria annulata* F. (Hym., Chalcididae), *T. oryzae* and *Trichospilus diatreae*.

4 Discussion

One hypothesis may explain the sigmoid growth of the pest and the following destruction of the crops. At the beginning of the dry season, *P. xylostella* has a large number of high quality host plants available and the parasitoids are not yet present. There are, therefore, no restrictions on their abundance and so they multiply at their maximum capacity. Following a period of approximately 6 weeks, the quality of food begins to decline and the majority of the foliage has been consumed. Furthermore, the parasitoids begin to develop thus perturbing the moth population. The *P. xylostella* growth curve begins a decline which eventually stabilizes in September. At the same time, the level of parasitism rises to above 50%. All these factors contribute to the decline in the *P. xylostella* population to a low level at which it will stay until the rains become the principal factor in control of the pest in early November (Wakisaka et al., 1992; R. Monnerat, pers. comm.).

Table 2. *Hyperparasites of the two principal natural enemies of* Plutella xylostella *at Embrapa Hortaliças (n = 23 and 77 individuals respectively)*

Host	Species (all hymenopterans)	Percentage
Apanteles piceotrichosus	*Conura* (*Spilochalcis*) *pseudofulvovariegata* (Becker) (Chalcididae)	60.9
	Trichomalopsis oryzae (Risbec) (Pteromalidae)	26.1
	Haltichella sp. (Chalcididae)	13.0
Diadegma leontiniae	*Conura* (*Spilochalcis*) *pseudofulvovariegata* (Becker) (Chalcididae)	58.4
	Aphagnomus fijiensis (Ferrière) (Ceraphronidae)	23.4
	Haltichella sp. (Chalcididae)	6.5
	Basileucus sp. (Ichneumonidae)	3.9
	Brachymeria annulata Fabricius (Chalcididae)	3.9
	Trichomalopsis oryzae (Risbec) (Pteromalidae)	2.6
	Trichospilus diatreae (Cherian & Margabandha) (Eulophidae)	1.3

The percentage values are the proportion of each parasitoid in observed hyperparasitism rates.

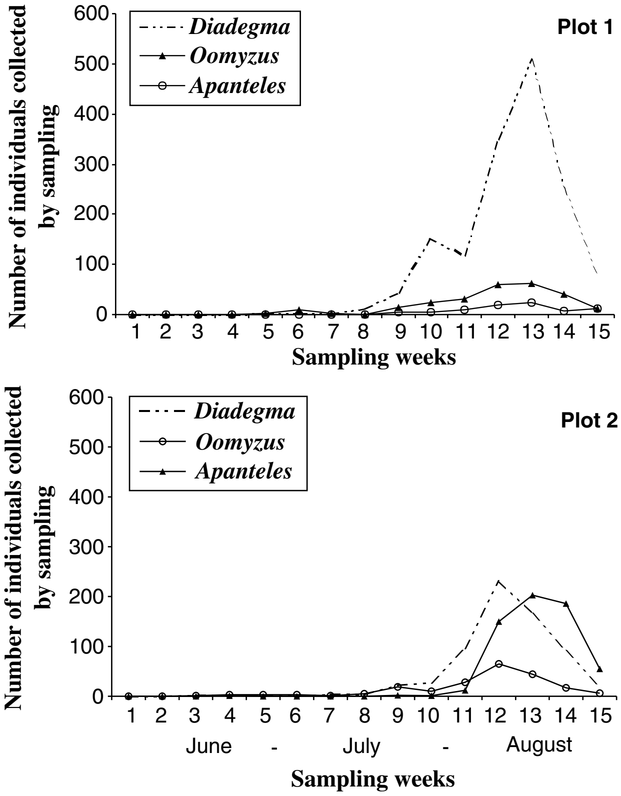

Fig. 2. *Major parasitoids observed overtime on plots at Embrapa-Hortaliças (Brazil) during the first crop*

Table 3. *Average number of parasitoids from* Plutella xylostella *populations at Embrapa Hortaliças during the weekly samplings*

Parasitoids	Plot 1	Plot 2	Calculated *t* (d.f. = 14)
Diadegma	100.8	44.1	2.87 – P < 0.05
Oomyzus	17.6	13.7	1.39 – NS
Apanteles	5.4	40.7	2.03 – NS (P < 0.07)
All parasitoids	123.8	98.5	1.87 – NS

Some parasitoid species appear to have their own phenological preferences when it comes to attacking the host. The *D. leontiniae* parasitism rate increases from one instar to the next, suggesting that this species attacks all instars. This behaviour differs from that of *Diadegma eucerophaga* (Horstm.) (Hym., Ichneumonidae) in Taiwan and Indonesia which do not attack the L4 instar (Talekar and Yang, 1991). On the other hand, *A. piceotrichosus* exclusively attacks the L2 larvae; the larvae that were collected at L3 and L4 instars had been previously parasitized during L2.

The parasitoid populations did not change in the same way in the two plots (fig. 2). In plot 1, *D. leontiniae* was in the majority and *A. piceotrichosus* is pratically absent. In plot 2, the two species were found in approximately equal numbers. The change in population of *O. sokolowskii* was the same in the two plots. Matched Student's *t*-tests were used to compare each pair of weekly samples taken from the plots to verify that the parasitoid populations were significantly different from one plot to the other. A $\sqrt{p}$ transformation was taken before the analysis in order to fix a high standard error that resulted from the large variations observed from one week to another. This type of transformation is possible when the parasitoids pick each larva they encounter only one time and move about often in search of new hosts thus presenting a random distribution (Lloyd, 1940). The analysis showed that only the *D. leontiniae* populations showed significant differences in development between the two plots ($P < 0.05$). *Apanteles piceotrichosus* just reached the 95% threshold (table 3). This might be explained by a slight temporal shift in development of the two plots which the *t*-test does not take into account and that reduces the differences between the pairs. This test also shows that *O. sokolowskii* develops in each plot. This could be the results of its density-independent habits. In the same way, the global number of parasitoids harvested was not significantly different between the two plots and their combined action was the same on the two plots. It is not possible here to explain the existence of these significant differences between plots.

The fact that *C. plutellae* and *Actia* sp. were rare is difficult to explain. Perhaps they suffered from competition with *A. piceotrichosus* and especially with *D. leontiniae*, which may also explain why the few specimens found were at the beginning of the cropping season before the dominant species were able to develop. A similar example of competition was observed between *C. plutellae* and *Diadegma semiclausum* (Hellen) (Hym., Braconidae) in Florida, preventing successful introduction of the former in this area (Hu et al., 1998).

These studies indicate a high level of diversity among the hyperparasites, approaching that found in the Mediterranean climatic region which is thought to be the centre of origin of *P. xylostella* and its guild of parasitoids and where a long co-evolution has taken place (Hardy, 1938; Mustata, 1992). It was higher than that observed by Ferronatto and Becker (1984) in the South of Brazil, with only three parasitoids and no hyperparasites. In contrast, Brasilia is a new city (inaugurated in 1960) and yet, in less than 40 years, populations of *P. xylostella* moved in along with the guild of seven parasitoids and six hyperparasites. This can be easily explained for *P. xylostella* as it is an excellent migrator (Chu, 1986) but is more difficult to explain for the guild. One would have to suppose a massive introduction of these species during the transport of cabbage plants (Shelton et al., 1996) or possibly that they were already present on other hosts. This appears to be the case for *T. diatreae* which originally also attacked other Lepidoptera, principally Noctuidae but is a pupal parasitoid of *P. xylostella* in Jamaica (Alam, 1992).

Only *Haltichella* sp. males were found in the course of this study. It is possible that the females develop on another host that was not recorded (G. Delvare, pers. comm.). The low level of hyperparasitism did not seem to have an effect on the populations of parasitoids as these developed rapidly following their exposure to *P. xylostella* with a latent period typical of that found in host–parasite interactions. Three species of hyperparasites present in very small numbers were common to *D. leontiniae* and *A. piceotrichosus*.

5 Conclusions

It will be necessary to continue these studies in order to observe the future evolution of *C. plutellae* and *Actia* sp. and to learn what becomes of them in the face of long-term competition by other species. This 6-month observation represents only a glimpse of the population dynamics of these species. Only a multi-year study will provide an understanding of the inter-seasonal and inter-annual variations that can exist. It will also be necessary to have more weather data at the plot level and principally the installation of an anemometer to ascertain the influence of the wind and to install sticky traps to verify possible migration from one plot to another. The phenological preferences of the parasitoids should be confirmed in the laboratory under controlled conditions with the possibility of exposing all the larval instars of *P. xylostella* simultaneously, in choice tests.

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