

The Egg Parasitoids of *Thaumetopoea pityocampa* in the Atlas Mountains near Marrakech (Morocco)

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Studies were performed on 25 egg batches of *Thaumetopoea pityocampa* (Den. & Schiff.) collected on *Pinus pinaster* Ait. on 29.XI.1995, in the Atlas Mountains of Morocco near Marrakech at 1400–1800 m above sea level. All the egg masses had been deposited in the autumn of 1995 and were exposed to the parasitoids throughout the developmental period of the host. In 1996, the egg batches, kept singly in test tubes, were observed almost daily. Emerged parasitoids were recorded and separated. The final analyses were made in November 1996 based on the meconia and remains of the emerged or the dead parasitoids in the eggs. In all cases, oviposition occurred from the base to the tip of the needles, distances varying up to 62 mm from the base. The mean number of eggs per batch was 175 (range 34–245), the number of egg-rows varied between 6 and 11, and a 1-cm egg-row contained a mean of 9 eggs. Caterpillars hatched from 72.7% of the eggs; total mortality of the eggs was thus 27.3%. The impact of egg parasitoids was 21.4%. Most of the parasitized eggs were attacked by *Baryscapus servadeii* (Dom.) followed by *Ooencyrtus pityocampae* (Mercet). Males (1.5%) were found only in *B. servadeii*. The emergence rate of *O. pityocampae* was much higher in the year of host oviposition than in the following year. *B. servadeii* emerged in equal numbers before and after hibernation, and in the subsequent year in equal numbers in spring and autumn. The high rate of emergence of *B. servadeii* in April–May is discussed in relation to the embryonic development of *Thaumetopoea bonjeani* (Powel) until the end of winter, as an alternative host of *B. servadeii* in the Atlas region.

KEY WORDS: *Thaumetopoea pityocampa*; egg parasitoids; *Baryscapus servadeii*; *Ooencyrtus pityocampae*; Morocco.

INTRODUCTION

In Morocco, *Thaumetopoea pityocampa* (Den. & Schiff.) is the most important pest of various pine species; in higher regions it also attacks *Cedrus atlantica* Man. (3). Aerial control of the pine processionary caterpillars has been carried out since 1979 with a microbial insecticide based on *Bacillus thuringiensis* (*B.t.*) or with diflubenzuron. Today an average of 10,000–15,000 ha/year are treated according to economic, ecological, and touristic criteria and constraints (6). For monitoring mass outbreaks, the following methods are used: mapping of winter nests, application of pheromone traps, determination of the diapause rate, and prediction of the level of infestation (7).

The maximal flight period of *T. pityocampa* was determined by pheromone trapping and found to be between July and September, depending on the region and altitude. At

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Marrakech the main flight period observed in 1988 was at the end of August at 1200–2100 m a.s.l. and at the end of September at 600–1200 m a.s.l. (4). Directly after emergence the females copulate and oviposit, mostly on the same night (3,10).

During the last few years a method was developed for determining the egg parasitoids by means of their meconia inside the eggs after emergence of the adults (11,12). The method was successfully applied by Tsankov *et al.* (16) in various regions of Bulgaria. The various parasitoids emerged before and after collection of the egg batches and their impact could be determined at any season of the year.

Baryscapus servadeii (Dom.) and *Ooencyrtus pityocampae* (Mercet) are known as the main solitary egg parasitoids from various regions of Morocco (1). In the present study, investigations were conducted into the impact of these natural enemies on host mortality in Morocco in scattered pine stands near Marrakech.

MATERIALS AND METHODS

Twenty-five egg batches of *T. pityocampa* were collected 50–60 km SE of Marrakech at Tahanaoute on *Pinus pinaster* Ait. trees at 1400–1800 m a.s.l. on 29.XI.1995 by the first author assisted by Ing. A. El Hassani and Prof. Dr. A.J. Bakri, Marrakech. All egg batches had been deposited in the autumn of 1995 and were exposed to the parasitoids throughout the developmental period of the host. The egg batches were found on scattered trees at a height of 1.5–2.5 m. The material was transferred directly to Hannover and from there mailed to the Forest Research Institute at Sofia for further observations during the emerging periods of the parasitoids. For that, the egg batches were placed singly in test tubes plugged with cotton, after some measurements had been taken. Then, they were preserved at room temperature under laboratory conditions (20–22°C).

During the subsequent year almost daily observations were made starting from 14.I.1996 (after removing the scales). The emerged egg parasitoids were removed immediately and separated in plastic capsules for determination. The final analysis followed in November 1996 at the Department of Zoology-Entomology, University of Hannover. Eggs without a hole in the shell were opened carefully and the meconia and remains of the emerged or dead parasitoids were determined by means of a stereomicroscope ($\times 40$ magnification) (16). An almost daily control was necessary to recognize the egg in which the emerging parasitoid had developed by a small hole and ascribe the meconium left to the emerged parasitoid.

RESULTS

The 25 egg batches studied contained 4,373 eggs, the mean per batch being 175 (range 34–245) eggs. The number of egg-rows per batch varied between 6 and 11; a 1-cm egg-row contained a mean of 9 eggs. The length of the needles on which eggs were deposited varied between 43 and 116 mm (mean, 89.3 mm) and the length of the egg batches varied from 8 to 37 mm (mean, 26 mm), with a diameter of 2.7–4.7 mm. Most of the egg batches were wrapped around two needles, only two were found on one needle, and four around four needles. The distance of the egg batches to the base of the needles varied from 1 to 62 mm. In all cases oviposition occurred from base to tip of the needles.

All together 4,373 eggs (100%) were used to study parasitism rate. *T. pityocampa* caterpillars hatched from 3,179 eggs (72.7%). Among 1194 unhatched eggs (27.3%

mortality), 64 (1.5% of the total number of eggs investigated) caterpillars died without opening the eggshell, 18 (0.4%) were found dead in the egg with an opening, 115 (2.6%) eggs were sterile (with dried-up yolk) and 63 (1.4%) eggs were found without any remains in them. The impact of egg parasitoids was 21.4% (934 eggs).

Among the 934 parasitized eggs, 712 (76.2%) were attacked by *B. servadeii* and 188 (20.1%) by *O. pityocampae* (Table 1). The remaining 34 (3.6%) larval parasitoids could not be determined. More detailed investigations showed that not all parasitoids emerged, since some died inside the eggs at various developmental stages. From *O. pityocampae* only females emerged. In *B. servadeii*, 1.5% males were found emerging after collection of the egg batches. In eggs parasitized by *B. servadeii*, head parts of the caterpillars were found. This was the case in 49 eggs (15.1%) from which adults emerged before (324), and in 11 eggs (3.3%) after (336), collection of the batches and in 10 eggs in which the parasitoid larvae died. In eggs parasitized by *O. pityocampae*, no remains of caterpillars were observed. The data show that *B. servadeii* parasitized more eggs in advanced developing stages of the host embryo than did *O. pityocampae*. There was no indication that the developmental stage influences the length of diapause of the eulophid.

TABLE 1. Analysis of the parasitized eggs of *Thaumetopoea pityocampa*

	<i>Baryscapus servadeii</i>	<i>Oencyrtus pityocampae</i>
Number of eggs observed	712 (100%)	188 (100%)
Number of adults emerged before collection of egg batches (49 with remains of caterpillars)	324	159
Number of adults emerged after collection of egg batches (11 with remains of caterpillars)	336 (5 males)	8
	} 660	} 167
Number of parasitoids which died in eggs		
as adults without opening	16	5
as pupae	21	11
as larvae	15	5
	} 52 (7.3%)	} 21 (11.2%)
Number of undeterminable larvae of parasitoids	34 (3.6%) of all parasitized eggs	

Although the egg batches were placed from the beginning of January 1996 at temperatures appropriate for the development of adult parasitoids, no emergence of *B. servadeii* took place before the end of April 1996. Until the end of May, 166 adults were collected from the test tubes containing egg batches. No adults appeared during June and July. Emergence started again at the end of August and lasted until about 20.IX.1996 (Fig. 1). During the autumn period 165 adults were collected from the batches in the test tubes. Males were found only in autumn.

The small number of *O. pityocampae* obtained (Table 1) emerged from 29.IV. to 5.VII.1996. Most adults of the encyrtid emerged before the winter period. In *B. servadeii*

Fig. 1. Pattern of *Baryscapus servadeii* emergence in 1996 from egg batches of *Thaumetopoea pityocampa* deposited in autumn 1995 near Marrakech at 1400–1800 m a.s.l. 1,2,3 refer to respective 10-day periods in each month.

Fig. 2. Oviposition pattern of *Baryscapus servadeii* (B.s.) and *Ooencyrtus pityocampae* (O.p.) in egg batches of *Thaumetopoea pityocampa* near Marrakech.

a slightly greater number of adults appeared after winter time than before hibernation. In the hibernating specimens diapause was prolonged only in one-half of the individuals until the following autumn and the other half emerged in spring (Fig. 1).

If one divides the egg batches studied into five equal parts, it is obvious that *B.*

servadeii preferred the first and last (5th) part of the batches and *O. pityocampae* emerged more frequently from the top part (5/5) (Fig. 2).

DISCUSSION

The mean number of eggs per batch in Morocco was relatively low, as had been found in Algeria (15) and Israel (8). This agrees with the observation that, in *Thaumetopoea* species, the mean number of eggs per batch is reduced from *ca* 250 in the northern areas of distribution (16) to *ca* 150 in the southern regions.

In Morocco, near Marrakech, *B. servadeii* was the most frequent parasitoid followed by *O. pityocampae*. The same was observed in Algeria (15), in northern Greece (2) and Israel (5,8). In southern regions of Greece and Bulgaria, *O. pityocampae* was more abundant than *B. servadeii* (16). In Italy, the distribution of both egg parasitoids depends on the geographical region (12).

Detailed studies showed that *B. servadeii* parasitized the host embryos at a higher rate in advanced stages than did *O. pityocampa*. The same was found in Algeria (15), Israel (5) and Bulgaria (14). This seems to be an adaptation to the host development, because *O. pityocampae* has much difficulties in surviving in eggs in which the host embryo has reached a developmental stage with sclerotized head and mouth parts (8).

For Italy, Tiberi (13) mentioned that there is a clear predominance of the eulophid over the encyrtid, which may depend on the better adaptation and resistance of the former to temperatures above 30°C. This might be substantiated by the often high mortality of the encyrtid found in the egg batches from Israel (8) and in southern Bulgaria (16). Also in Morocco a higher percentage of *O. pityocampae* (11.2%) than of *B. servadeii* (6.8%) died in the eggs. It is known from Bulgaria that the percent reduction of egg parasitoids by death in the eggs depended on the location studied, the year in which the investigations were performed, and the season in which the egg batches had been collected. The number of dead *O. pityocampae* (adults, pupae and larvae) was much higher in autumn than in spring collections (16), indicating the important influence of the summer conditions. The temperature of the egg batches could rise up to 14°C higher than that of the air, when they were exposed to solar radiation (9).

As found in Algeria (15), also in Morocco the rate of emergence of *O. pityocampae* was much higher before than after collection of the egg batches; the diapausing number was very low.

In *B. servadeii* equal numbers of adults were found in autumn and spring. It was surprising that after hibernation the emergence pattern of the eulophid showed two distinct peaks, never found in other regions. Normally, a diapause of 11–12 months and a perfect synchronization with the next host generation can be observed, which was partly found in the present study, too. However, in the Atlas region there are two *Thaumetopoea* species. Besides *T. pityocampa*, *T. bonjeani* (Powell) is widely distributed in higher regions, where *Cedrus atlantica* Man. is the host plant (3). Oviposition of *T. bonjeani* takes place in August–September on small twigs and the eggs are also covered with scales. The eggs hibernate and the larvae do not hatch before March–April of the following year. Demolin (3) reported that *T. bonjeani* eggs are also attacked by *O. pityocampae* and, presumably, by *B. servadeii* too. Considering the laboratory conditions under which the present observations were conducted, it seems possible that the adults of *B. servadeii* which emerged in the spring may find, for multiplication, eggs of *T. bonjeani* in an advanced

developmental stage. This may be a way for the parasitoids to reach the next generation of *T. pityocampa* and *T. bonjeani* for multiplication. On the other hand, *B. servadeii* specimens can survive on honeydew for several months under laboratory conditions to reach the next host generation. It is remarkable that the eulophid emerges in southern Bulgaria (Marikostino) from April to July (16). *O. pityocampae* has a shorter adult lifespan than *B. servadeii* (8). Halperin (5) reported that after hibernation only a small percentage of *B. servadeii* emerged in the spring in Israel; this was found also in Greece (2) and Bulgaria (16).

As had been observed in Algeria (15) and in Israel (8), also in Morocco *B. servadeii* parasitized more eggs at the base and top of the egg batch than in the middle parts. In Italy, the eulophid was more frequently present in the apical part (13). *O. pityocampae* preferred only the top part for oviposition, contrary to the findings in Italy (13), Israel and Algeria, where the basal part was preferred by the encyrtid. No clear preference for an egg batch sector was found in Bulgaria for either parasitoid (16).

In the present study the hatching rate of the caterpillars was relatively high (72.7%), although the parasitoids could attack the host eggs throughout the embryonic period. It may be of special interest that a small proportion of eggs (1.4%) was laid without any contents, which was observed first in Bulgaria (16). The question arises how it is possible for the female to oviposit eggs without yolk, which were found recently in egg batches sampled in various countries (unpublished). There was no indication that those eggs were emptied by predators (Heteroptera). As reported from other regions (15,16), in the eggs presently studied, holes were often observed on the side of the eggshell (not counted here) through which the parasitoids emerged regardless of the species. Considering all the other factors involved in the reduction of the pest eggs, 78.2% of the total mortality was caused by parasitoids.

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