

Scientific note

Emergence patterns of *Orgyia ericae* (Lepidoptera: Lymantriidae) parasitoidsPatrones de emergencia de los parasitoides de *Orgyia ericae* (Lepidoptera: Lymantriidae)CUI YA-QIN¹, SHENG MAO-LING², LUO YOU-QING³, and ZONG SHI-XIANG⁴

Abstract: To provide guidance on the utilization and conservation of the forest defoliator *Orgyia ericae* parasitoids, we survey its parasitoid species. We identified the developmental stages associated with the different parasitoids, and the emergence pattern of adult parasitoids. Observations of hatching were conducted hourly from 7am to 12pm until all adults had emerged. Pupation time, emergence patterns, and the abundance of *Exorista larvarum* parasitoids were recorded in detail. The abundance and daily emergence patterns of *Bracon (Habrobracon)* sp., and *Tetrastichus* sp. were analyzed. *Bracon (Habrobracon)* sp. and *E. larvarum* both had only one emergence peak, whereas *Tetrastichus* sp. had two. The daily emergence of *Bracon (Habrobracon)* sp., *Tetrastichus* sp. and *E. larvarum* peaked at 3 to 5pm, 3 to 5pm and 7 to 8am, respectively. The *E. larvarum* pupation distribution was characterized by two peaks.

Key words: Parasitoids. *Bracon (Habrobracon)* sp. *Tetrastichus* sp. *Exorista larvarum*. Grey-spotted tussock moth.

Resumen: Para proveer guías acerca de la utilización y conservación de los parasitoides del defoliador forestal *Orgyia ericae* se inventariaron sus especies de parasitoides. Se identificaron los estados de desarrollo del lepidóptero con las distintas especies de parasitoides así como sus patrones de emergencia. Se adelantaron observaciones de emergencia desde las 7am hasta 12pm hasta que todos los adultos emergieron. Tiempo de pupación, patrones de emergencia y abundancia del parasitoides *Exorista larvarum* se registró en detalle. Se analizaron la abundancia y patrones de emergencia de *Bracon (Habrobracon)* sp. y *Tetrastichus* sp. *Bracon (Habrobracon)* sp. y *E. larvarum* exhibieron un solo pico de emergencia mientras que *Tetrastichus* sp. muestra dos picos. La emergencia diaria de *Bracon (Habrobracon)* sp., *Tetrastichus* sp. y *E. larvarum* fue mayor entre las 3 a 5pm, 3 a 5pm y 7 a 8am, respectivamente. La pupación de *E. larvarum* mostró dos picos.

Palabras clave: Parasitoides. *Bracon (Habrobracon)* sp. *Tetrastichus* sp. *Exorista larvarum*. Polilla de penacho de manchas grises.

Introduction

Orgyia ericae (Germar, 1824) is a defoliator moth of the Lymantriidae family (Lepidoptera) (Xu 1980; Wu *et al.* 1982). It is distributed mainly in Heilongjiang, Jilin, Liaoning, Shaanxi, Gansu, Qinghai, and Shandong provinces, in the autonomous regions of Inner Mongolia and Ningxia in China, and in the former Soviet Union and Europe (Zhao 1978; Xiao 1992; Dapkus 2004, 2010). *O. ericae* is an important pest of trees. Given the economic and ecological importance of the species it attacks, *O. ericae* has a major impact in the regions where it is found. In recent years, it has been frequently reported to attack *Hedysarum fruticosum* Pall. var. *mongolicum* (Turcz. ex B. Fedtsch., 1902) (Fabaceae), *Caragana*, *Hedysarum scoparium* (Fisch. et C. A. Mey., 1841) (Fabaceae), *Calligonum mongolicum* (Turcz., 1832) (Polygonaceae), *Ammopiptanthus mongolicus* (Maxim. ex Kom.) (S. H. Cheng, 1959) (Fabaceae) and other desert plants, occurring in a large area of desert shrubbery of regions such as Inner Mongolia, Ningxia and Qinghai. These species are important for desert shrubbery in northwest China, and play a particularly key role in landscape stability and desertification control. They are resistant to drought, sand burial, wind erosion, sand, and barren soil, and grow rapidly. These plants can be used as fodder

for livestock (except *A. mongolicus*), and as ingredients for Chinese medicine, also edible oils can be extracted from seeds of these plants (Liu *et al.* 1985; Liu *et al.* 1987). Studies of the biological characteristics and life history of *O. ericae* have shown that *O. ericae* has two generations per year (Xu 1980; Xiao 1992; Wang & Liu 2002; Wang *et al.* 2009). Individuals overwinter as eggs in cocoons, which hatch in the middle of May. The newly hatched larvae undergo six instars of four to five days each, usually feeding on leaves. The dispersion of larvae depends on wind. Pupation begins in mid June on the branches of plants, and adults emerge after approximately ten days, in early July. The wingspan is 21-28mm for males, while females are wingless and release sex pheromones that attract mates to cocoons, where eggs are laid. Each female adult can produce, on average, approximately 250 eggs. Males have obvious phototaxis. The second generation of eggs begins to hatch in the middle of July, with pupation beginning in mid to late August and adult emergence in early September. The eggs overwinter in cocoons after mating. Although the biological characteristics and parasitoids of *O. ericae* (Wang & Liu 2002; Yu *et al.* 2007; Wang *et al.* 2008; Sun *et al.* 2008; Li *et al.* 2009), and the sex pheromone (Chen *et al.* 2010; Chen *et al.* 2011), nuclear polyhedrosis virus and polyhedrin gene sequence of *Orgyia ericae* (Zhang *et al.* 1991; Dai & Zu 1996; Zu

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& Dai 1997; Yang *et al.* 2006), have been intensely studied, there are currently no reports describing the emergence patterns of adult *O. ericae* parasitoids. To provide guidance on the utilization and conservation for parasitoids of *O. ericae*, we investigated *O. ericae* parasitoid species and the emergence pattern of adult parasitoids.

Materials and Methods

A total of 982 cocoons of *O. ericae* were collected from *H. scoparium* in Hangjinqi, Erdos, Inner Mongolia, on July 4, 2008. All cocoons were cultured and observed in two loosely airtight containers placed in a rearing room at $24\pm 1^\circ\text{C}$, $50\pm 10\%$ relative humidity and a photoperiod of 14:10 (L:D).

Observations of *O. ericae* egg hatching as well as the identification of parasitoid species and measurements of their stage and abundance were conducted hourly from 7am to 12pm from July 7, 2008, until all adults had emerged. In order to represent a proportion of parasitism of all male and female cocoons, all cocoons collected were dissected on August 14, 2008. *O. ericae* cocoons were also classified with respect to sex, based on their morphological differences. Female cocoons present one mating hole, and differ in length and color: the female pupa is 15mm long and characterized by a yellow and brown color, whereas the male pupa is approximately 8mm long and it is dark brown.

To complete the next stage of their life cycle, the larvae of *Exorista larvarum* (Linnaeus, 1758) (Tachinidae) (S. M.-L.) must break out of the *O. ericae* cocoon and pupate. All the pupae of *E. larvarum* were collected in vitro, and the time of pupation and emergence, as well as the quantity of parasitoids, were recorded. We used LSD multiple comparisons to analyze and identify where differences in the peaks of emergence occurred.

Results

Parasitoid species. Out of the 982 cocoons of *O. ericae*, 485 male cocoons and 384 female cocoons were parasitized, representing a parasitism of 88.18% and 88.89% for male and female cocoons, respectively. Eight parasitoid species were identified, including the following Hymenoptera, numbers within brackets indicate their abundance: *Bracon (Habrobracon)* sp. (Braconidae) (174), *Itoplectis viduata* (Gravenhorst, 1829) (Ichneumonidae) (S. M.-L.) (11), *Pimpla disparis* (Viereck, 1911) (Ichneumonidae) (S. M.-L.) (3), *Eutanyacra picta* (Schrank, 1776) (Ichneumonidae) (S. M.-L.) (3), *Tetrastichus* sp. (Chalcidoidea) (S. M.-L.) (180), *Aprostocetus* sp. (Chalcidoidea) (S. M.-L.) (1), *Brachymeria lasus* (Walker, 1842) (Chalcidoidea) (S. M.-L.) (2), and the Diptera *Exorista larvarum* (Linnaeus, 1758) (Tachinidae) (445).

Adult emergence period of parasitoids. *Bracon (Habrobracon)* sp. and *Tetrastichus* sp. were the most frequent Hymenoptera parasitoid species in the sample. By contrast, only 11 adults of *I. viduata* emerged, and the remaining species of parasitic wasp were represented by three or less individuals. There were 445 adults of *E. larvarum* in our sample.

For *Bracon (Habrobracon)* sp. it took 11 days for adults to begin to emerge and emergence occurred from the 7th to the 22nd July (Fig.1). Peak emergence corresponded to 54

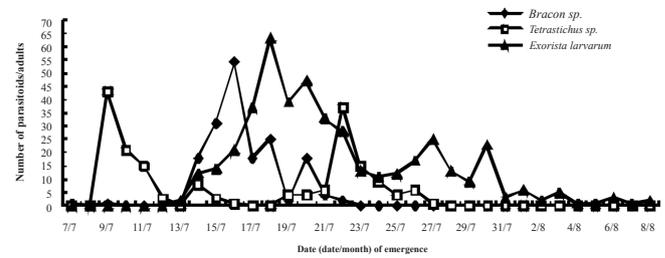


Figure 1. Adult emergence periods of *Bracon (Habrobracon)* sp., *Tetrastichus* sp. and *E. larvarum* adults.

adults (31% of the total number of *Bracon* sp. individuals that emerged). Eclosion took 16 days for *Tetrastichus* sp. and occurred from the 9th to the 27th July (Fig.1). Emergence in this species was characterized by a bimodal pattern of emergence, with the first peak of emergence being slightly higher than the second. Adults of *E. larvarum* emerged from mid July to early August (Fig.1). There were three small peaks of emergence concentrated in mid and late July, followed by a low rate of emergence until the 10th August.

Daily emergence rhythm of parasitoids. The emergence of *Bracon (Habrobracon)* sp. peaked between 11 and 12am and between 3 and 5pm, with most emergences occurring between 3 and 5pm (Fig. 2). *Tetrastichus* sp. emerged most frequently from 7am to 8pm, with two emergence peaks at 8 to 10am and 3 to 5pm, with the second peak being slightly higher (Fig. 2). The daily emergence of *E. larvarum* was characterized by a high peak of emergence from 7am to 8pm and several low peaks of emergence throughout the day (Fig. 2).

Pupation range of *Exorista larvarum*. *E. larvarum* pupation lasted from 7 to 34 days and two emergence peaks were observed, accounting for respectively 40% (first peak) and 48% (second peak) of all emergences (Fig. 3).

Our results show that the parasitoid species *Bracon (Habrobracon)* sp., *Tetrastichus* sp. and *E. larvarum* emerged at different times in July, with distinctive differences in the timing of their peaks of eclosion. The consecutive peaks of eclosion may be the consequence of long-term co-evolutionary competition processes among these three parasitoid species, which would have resulted in the minimization of inter-species competition and parasitism of

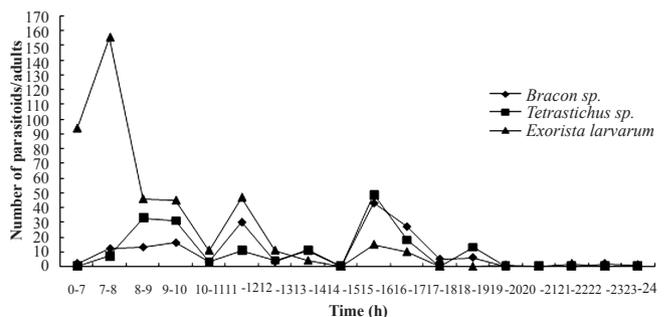


Figure 2. Daily emergence patterns of *Bracon (Habrobracon)* sp., *Tetrastichus* sp. and *E. larvarum* adults.

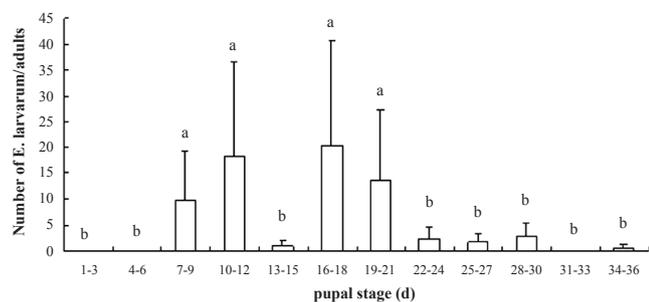


Figure 3. Pupation time of *E. larvarum* in days (Means \pm SE, and the different letters indicate significant differences ($P=0.05$) based on LSD multiple comparisons).

the same host at different periods. This conjecture may also explain how these parasitoid populations are maintained in balance.

Although this study has confirmed that the emergence of *Tetrastichus* sp. adults is characterized by two peaks, it is still not clear whether *Tetrastichus* sp. is a hyperparasitoid insect. Conversely, a large number of *E. larvarum* adults emerged between midnight and 7am, but there are no data on the number of eclosions per hour, precluding the determination of specific emergence times. In addition, because the number of individuals belonging to *I. viduata*, *P. disparis*, *E. picta*, *Aprostocetus* sp. and *B. lasus* was low, we were unable to determine their patterns of eclosion, an issue that should be addressed in future studies.

Most adults of *O. ericae* emerge in early July, mate and lay eggs. Newly hatched larvae of the second generation emerged in mid July, and mature larval pupated in mid and late August. Adults emerged in early September. Based on the life cycle and habit of *O. ericae*, *Tetrastichus* sp. might parasitize eggs of *O. ericae*, *Bracon* (*Habrobracon*) sp. and *E. larvarum* might attack larvae of *O. ericae*. Similar results were reported by Haiyan Li *et al.* (2009), whose anatomical observations of the parasitoids of egg cocoons of *O. ericae* showed that each developmental stage of *O. ericae* is parasitized by a different parasitoid species. These findings could permit the selection of the most appropriate parasitoids according to the developmental stage of the host, as well as the selection of suitable prevention and control periods based on adult emergence patterns of parasitoids and the biological characteristics of the host.

Chemical control and cocoon extirpation are commonly used to prevent and control *O. ericae* (Yu *et al.* 2007; Sun *et al.* 2008; Wang *et al.* 2009; Luan *et al.* 2010). However, chemical control and cocoon extirpation would also adversely affect parasitoid population numbers, reducing the effectiveness of this natural control of *O. ericae*. Therefore, it might be appropriate to reduce these artificial control measures during adult emergence periods of parasitoids. Simultaneously, through investigations of *O. ericae* parasitoid species and the emergence patterns of adult parasitoids, it might be possible to choose a suitable time for the release of parasitoid species into the field to control population numbers of *O. ericae*.

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