THE OVIPosition AND LIFE CYCLE OF ANTHRAX TIGRINUS,  
[DIPT.: BOMBYLIIDAE]  
A PARASITE OF CARPENTER BEES [HYM.: XYLOCOPIDAE]

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Xylocopa virginica (L.) is readily parasitized by Anthrax tigrinus (DE GEER). By using an x-ray technique and by observing field and laboratory populations of carpenter bees and their bombyliid parasites we located the parasite's eggs and followed their developmental stages through emergence. The acquisition of details on oviposition and associated behavior was facilitated by using a stereoscan electron microscope.

Biological observations on larvae of Xylocopa spp. attacked by bee flies of the genus Anthrax were first recorded by ANGUS (1868). The most thorough work was conducted by NININGER (1916), who studied A. delila (LOEW), a parasite of X. tabaniformis orpifex SMITH, in Southern California. According to MARSTON (1970), who revised the tigrinus group of New World Anthrax, there are 4 species that are parasitic upon carpenter bee larvae. He recorded the following host-parasite relations between members of the genera Anthrax and Xylocopa: A. delila (LOEW) from X. tabaniformis orpifex SMITH; A. simson simson FABRICIUS from X. augusti LEPELETIER; A. tigrinus (DE GEER) from X. virginica (LINNAEUS) and A. xylocopae MARSTON from X. californica arizonensis CRESSON. From these data it is apparent that, in contrast to the formerly assumed polyphagy of Anthrax species (Hurd, 1959), this parasite is monophagous.

The emergence of adult bee fly parasites and/or their association with carpenter bees have been observed numerous times (Hurd, 1959). NININGER (1916) gave an exact account of the fly's developmental history during the spring. A young larva of the parasite was found first upon the bee bread within the provisioned cell, where it wandered about for approximately 3 weeks. During that time the minute larva fed on pollen. Thereafter, it attached itself to the young host larva but grew only very little in size, as long as the host was not fully grown. Thereafter, when the host was 4-5 weeks old, the parasite grew very quickly, reaching maturity about 5 days later. After 12-14 more days, the parasite pupated; the adults emerged 15-20 days later.

Additional important contributions to our knowledge of bee fly biology were made by ANGUS (1868). He saw an adult Anthrax "on the wing by one of the openings of Xylocopa cell" and later found small eggs on the wood, from which he obtained small larvae that seemed to him like those of Anthrax. However, identification was never certain.

To date, no study has established the exact nature and time of oviposition of these bee flies.
MATERIALS AND METHODS

During 1973-74, while studying the nesting biology of *X. virginica*, the authors were able to examine the oviposition habits and development of *A. tigrinus* in Athens, Georgia. By using X-rays the larval development of *A. tigrinus* and the development of carpenter bees were studied *in situ* and in the laboratory. For the latter studies both hosts and parasites were isolated in small glass or plastic containers. Adult behavior and oviposition were examined in the field near nests of the hosts. The hooked hairs of the pupa, the terminal abdominal hairs of the female, and the eggs were examined and photographed with a Cambridge scanning electron microscope (SEM).

RESULTS

Adults emerged both in the field and laboratory from the end of May to the end of July with a peak in the first three weeks of July. During that period, they were seen in the field flying near wooden boards in the general area of their emergence. They approached the site, and rhythmically bent the abdomen forward under the thorax in a rapid, flipping motion to attach the 0.7 mm long eggs erect to the substrate. This process was repeated several times per minute. Every 5-10 minutes on the average, the female alighted on a board, rapidly extended the tip of her abdomen and rubbed it over the surface of the board (fig. 1, A). Simultaneously she gently moved her wings up and down. After less than one minute of this behavior, she again commenced to fly and oviposit.

A close examination of the eggs revealed that whereas they normally were white and smooth within the female, they were dark and rough-surfaced after deposition (fig. 1 D). The latter appearance was caused by a dense cover of debris that adhered to the chorion, and which originated in the tip of the female's abdomen. Two large and dense tufts of hair were present (fig. 2 A B) on the tip, they were clean when the fly emerged from its puparium, and later were rubbed against a soil covered substrate, gathering debris into a "perivaginal pouch" (Biliotti *et al.*, 1965) or "soil chamber" (Muehlenberg, 1971), through which the egg passed before being deposited.

Our examination with the SEM, revealed 2 types of hairlike extensions on the abdominal tip (fig. 2 A D), corresponding to the "hair wisp" of the 8th segment and the acanthophorites of the 9th segment respectively (Muehlenberg, 1971). The "hair wisp" occupies the entire abdominal tip except the area that surrounds the gonopore. Its hairs are thin and straight, and retain debris that is picked up from the substrates. They are on a retractable membrane which is extended (fig. 2 B) during the process of rubbing the substrate. The acanthophorites are in a V-shaped distribution flanking the gonopore on each side (fig. 2 C). They are club-shaped distally (fig. 2 D) and have a longitudinal channel facing away from the gonopore.

The ovipositional potential of the females was estimated by dissecting actively laying females, counting and observing the condition of the ova and ovaries. A female has 500 ovarioles in each ovary. In each ovariole there was one large developing oocyte and one mature oocyte. No ovarioles were found with more than one developed oocyte, and since the female was killed while ovipositing, the lateral oviducts were full of eggs which were enroute to the ovipositor. Based on the number of oocytes and eggs present it is safe to estimate that a female is capable of laying at least 2000-3000 eggs.