The Great Lakes Entomologist

Volume 26
Number 1 - Spring 1993 *Number 1 - Spring 1993*

Article 2

April 1993

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Recommended Citation

Chilcutt, Charles F. and Cowan, David P. 1993. "Methods for Artificial Rearing of Solitary Eumenid Wasps (Hymenoptera: Vespidae: Eumeninae)," *The Great Lakes Entomologist*, vol 26 (1)
DOI: https://doi.org/10.22543/0090-0222.1802
Available at: https://scholar.valpo.edu/tgle/vol26/iss1/2

METHODS FOR ARTIFICIAL REARING OF SOLITARY EUMENID WASPS (HYMENOPTERA: VESPIDAE: EUMENINAE)

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ABSTRACT

Solitary eumenid wasps of the genera *Ancistrocerus* and *Euodynerus* can be reared in small cages. Laboratory-reared larvae of the spruce budworm caterpillars, *Choristoneura fumiferana* (Lepidoptera: Tortricidae) are suitable prey.

Many problems in insect biology are difficult or impossible to study in a completely natural setting, thus making artificial rearing methods necessary for further advances. Generally, it is necessary to provide adults with conditions needed for maintenance, an appropriate environment for males and females to mate, proper oviposition stimuli for females, and an adequate diet for immature stages. Fulfilling these conditions for hunting wasps is relatively complex because females require: (1) specific materials (from the environment) for nest construction prior to oviposition; and (2) live arthropod prey for females to paralyze and provision for their offspring. Here we report successfully rearing, under artificial conditions, solitary eumenid wasps of the genera *Euodynerus* and *Ancistocerus*.

In nature, these wasps nest in hollow twigs and vacant insect borings (Krombein 1967). Within a cavity, a female lays an egg; she then hunts for and paralyzes caterpillars that are placed within the cavity or nest near her egg. When enough prey items have been placed in the cavity with the egg, the female then makes mud by mixing water and dry soil. She uses this mud to seal off a cell that contains her egg and its provisions. This process may be repeated in the same nesting cavity until it is filled with a linear series of cells containing her offspring. Observations by Steiner (1983) and by Veenendaal and Piek (1988) indicate that female eumenid wasps will engage in predatory and nesting behaviors within the confines of small cages. Such behavior makes large-scale artificial rearings possible.

MATERIALS AND METHODS

Eumenid wasps were obtained by rearing them from trap nests placed out in Kalamazoo and Iron counties, Michigan. Wasps were either removed from trap nests as larvae, or captured as young adults as they emerged from their nests. Males were transferred to a holding cage upon emergence, and two day

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post-emergence females were placed in the cage with the males (different ages) for mating. Both mated and unmated females were used in this study.

Captive rearings were carried out on the Western Michigan University campus during the summers of 1989–1991. Rearing cages were placed in a courtyard surrounded by a 3 story building. This allowed natural weather phenomena, but decreased sun exposure in the morning and evening.

We reared wasps in 60 cm × 60 cm × 60 cm cages constructed of plywood bottoms, with one side and top of glass, and three sides of aluminum screen (18×16 mesh). For access, a 15cm square hole in the corner of a screened side supported a 100cm long cloth sleeve that could be knotted. In 1989, cages were raised 4cm above the ground on boards to prevent rotting. In 1990 and 1991, cages were placed on wooden stands (60cm high), with tanglefoot applied to the legs to keep out pests.

All outdoor cages contained: (1) a petri dish supplied daily with sugar water, (2) a jar lid of dried clayey mud, and (3) a petri dish supplied daily with water. A microscope slide was placed inside the water dish to allow wasps that fell in the water (a frequent occurrence) an escape route. Generally, the sugar water dried quickly: however, the wasps moistened the crystals with water and ate.

Two or four females were placed in each cage, with each cage provided with two nests per wasp, wired to the inside screen or placed on the cage floor. The hole diameters of the nest sticks were the same as the sizes they selected in nature (5.6 mm, 6.4 mm, and 7.1 mm). The day after a nest was completed, as evidenced by a mud plug in the nest-hole entrance, the nest was removed and another nest was provided in its place.

To provide wasps with potential prey, diapausing first instars of the spruce budworm, *Choristoneura fumiferana* (Clemens) were obtained from the Canadian National Forestry Laboratory in Sault Ste. Marie, Ontario, and reared on commercial (Bioserve Corporation) diet, following instructions in Grisdale (1984). Collins and Jennings (1987) found spruce budworms to be a common prey (94% of prey found in trap nests) of *Euodynerus* and *Ancistrocerus* species in a spruce-fir forest. By placing budworms on the diet at the time of first-male emergence, prey items of suitable size (>2mm) were available when female wasps began hunting about 10 days later.

As an alternative to the commercial diet, we reared some budworms on a diet of tender buds of white spruce, *Picea glauca*. Expanding buds were cut early in the growing season and frozen for later use. For rearing budworm larvae, buds were thawed, sprayed with the same fungicide used with the artificial diet, and then placed in 30ml plastic cups. Attempts to rear budworms on mature spruce foliage were unsuccessful.

In 1989, 17 adult female *Euodynerus foraminatus* (Saussure), and one female *Parancistrocerus* sp. were placed in outdoor cages, with one cage containing four wasps and seven cages containing two wasps apiece, and observed from 23 June until 1 August. In 1990, 18 *Euodynerus planitarsis* (Bohart) and 8 *E. foraminatus* were placed in outdoor cages (six cages contained three *E. planitarsis* apiece and two cages containing 4 *E. foraminatus* apiece) on 15 June and observed until 21 September. In 1991, 13 *E. planitarsis*, 2 *E. foraminatus*, 2 *Euodynerus hidalgo* (Saussure) and 4 *Ancistrocerus antilope* (Panzer) females were placed in outdoor cages on 1 June and observed until 30 September.

Indoor rearings were attempted in 1991. Five *E. foraminatus* females were placed singly in pint jars; four were placed singly in gallon jars. Each jar contained two trap nests, a capful of mud, a capful of water, and white spruce shoots. Jar openings were covered with screening and the wasps were fed on honey smeared on this cover. Honey or sugar water provided needed carbohydrates for the wasps. Due to limited space in the jars, prey were removed from rearing cups and placed on the spruce in the jars.

RESULTS AND DISCUSSION

During 1989, all 17 female wasps entered nest sticks; however only 3 *E. foraminatus* hunted, captured prey, and provisioned nests. Beginning on 7 June, these 3 females completed eleven nests that produced adult offspring, 10 females and 9 males

During 1990, all 14 *E. planitarsis* females nested beginning on 30 June. They completed 59 nests that contained 127 provisioned cells, which produced 84 adults. Five of the 8 *E. foraminatus* females nested and completed 11 nests that contained 46 provisioned cells and which produced 35 adults. All of the offspring reared in 1990 were adult males, indicating that none of the parent females had mated. We reared parental females from larvae placed in vials, and transferred the newly emerged adults to cages with males for a day. We then transferred the females into the rearing cages that contained nesting supplies. Apparently the females were not fully mature and ready to mate when placed in the cage with the males. We avoided this problem in 1989 and 1991 by leaving larvae and pupae in their nests and allowing them to transform to adults and emerge on their own. One day later we placed them in cages with males and watched to be sure they mated.

In 1991, the first wasp began nesting in the cages on 7 June, apparently early due to unseasonably warm weather. Thirteen *E. planitarsis* completed 41 nests which contained 70 provisioned cells. One of 2 *E. foraminatus* females completed 2 nests with 3 provisioned cells. One of 4 *A. antilope* females completed 2 nests on the same day, each with one provisioned cell, before escaping from the cage. Two of the 3 *A. antilope* that did not nest captured prey without placing them in a nest stick. The *E. hidalgo* females showed no interest in prey, never displaying hunting or searching behaviors.

Attempts to rear wasps indoors in jars were less successful. Although 6 of the 9 wasps began nesting, mortality of the females was high. The primary problem was obtaining a balance between proper light and temperature conditions. Wasps tended to remain in their nest under artificial lighting (fluorescent) or when placed in naturally lit areas but not in direct sunlight. If placed in direct sunlight on warm days, temperatures in the jars soared and wasps died. Placing the jars in direct sunlight with partial shade seemed to help. Nests taken from the jars were damp, and most contained fungal growth. Apparently the heat and water provided for the wasps increased the humidity above safe levels. This problem did not occur outdoors in the better ventilated screen cages.

In cramped rearing containers, caterpillars often crawled behind objects where the wasps could not reach. Spruce twigs placed in the rearing jars provided a centralized hunting area where budworms tended to stay.

During the normal process of getting water and mud and returning to the nest to build mud partitions, several wasps were seen chewing on the caterpillars' silk and possibly their frass. Perhaps wasps were using something from these materials as additives to the mud partition. All observed wasps spent time searching over the mud provided them before collecting mud from a well chosen spot. Such behaviors indicate that selection of the right kind of mud (apparently cohesive enough for the wasp to mold) is important.

The low nesting success in 1989 (only 3 wasps nested) apparently was due to ants and earwigs (*Forficula* sp.) getting into the cages. Cages placed on boards near the ground were accessible to small insects that could get through cracks or the screen mesh. Earwigs entered the cages by crawling into the cage sleeve and falling into the cage when the sleeve was used. We later discovered (while opening nests) that earwigs sheltered in the nests, and possibly deterred wasps from nesting. However, several wasps barricaded earwigs in the ends of the nests with mud partitions. Three of 4 nests found this way successfully produced offspring. Ants were the most notable pest problem, because they competed with the wasps for budworm prey. Ants killed and dismembered budworms to remove them through the screen. When ants came upon wasps holding prey (which the wasps often do while waiting for the venom to work) the ants would grab onto the caterpillar and a tug-of-war ensued. The ants always came out the victor (observed >20 times).

In 1989, the cages were placed in an area where they were shaded during the warmer hours of the day (1200 to 1400 h), because we believed that direct sunlight would heat the cages to a deadly temperature. However, the limited nesting success of these wasps prompted us to place the cages in the open (i.e. direct sunlight all day) for subsequent studies in 1990 and 1991. Cut evergreen branches were placed on the tops of cages, thus creating shaded and sunny areas within each cage during the day. Only when air temperature exceeded 35° C were wasps observed resting for periods in the shade. One problem encountered by placing the cages in direct sunlight was high spruce budworm mortality. This problem was solved by placing the rearing cups that contained budworm larvae in the area of the cage shaded during mid-day.

Our increased success in rearing wasps after 1989, mainly was due to placing the cages on stands with tanglefoot around the legs. Such barriers eliminated all ants and earwigs from the cages, although we still removed an occasional spider. At no time during the rearing studies did we find nest parasites or parasitoids of either wasps or spruce budworms. Hence, we conclude that the increased nesting success from 18% of wasps in the total sample which layed eggs in 1989 to 63% in 1990 primarily was do to exclusion of ants which significantly impact solitary wasps' nesting success.

Mortality of *E. planitarsis* and *E. foraminatus* immatures reared in 1990 was only 31.2% compared to 45.3% for eumenids observed in nature (Cowan 1981). This difference (14.1%) is attributable to the absence of nest parasites, parasitoids, and predators. Most of the wasp mortality during our study ($>$ 60%) resulted from our clumsy handling of nests which caused injury to unhatched eggs or delicate immature wasps. Fungi and other unknown pathogens contribute to the remainder of the mortality.

We found the following factors most important for successful propagation of wasps: (1) Insure that female wasps have successfully mated; otherwise, only male offspring will result. (2) Supply adequate nesting resources i.e., nest sticks, carbohydrates (sugar or honey), water at all times, dried mud with adequate clay content, and potential prey larvae. (3) Daily exposure to sunlight, with partial shade to avoid overheating, is needed; also, adequate ventilation to control humidity. (4) Measures to exclude pests such as ants improve nesting success.

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