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Original Article

Notes on the Nesting Behavior of Four Solitary Wasps (Insecta: Hymenoptera) in India

Pham Huy Phong[1,2,*], Nguyen Thi Dinh[1], P. Girish Kumar[3]

[1]*Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam*

[2]*Graduate University of Science and Technology, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam*

[3]*Western Ghat Regional Centre, Zoological Survey of India, Eranhipalam, Kozhikode, Kerala- 673006, India*

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Abstract: India is one of the countries that has the highest biodiversity level of Hymenoptera in the Oriental region, as well as in the world. Hence, studies of its biology have received a large consideration from entomologists. In a course of study on Hymenoptera in Odisha state of the country in 2015, we observed the nesting behavior of several wasps and recorded their new nesting sites. Therefore, this study presents notes on the nesting behavior of the four Indian wasps, namely, *Chalybion bengalense* (Dahlbom) (Sphecidae), *Trypoxylon petiolatum* F. Smith (Crabronidae), *Delta esuriens* (Fabricius) and *Xenorhynchium nitidulum* (Fabricius) (both, Vespidae: Eumeninae). The first two wasps used man-made holes on the walls of a big temple for their nesting sites, fully stored paralyzed spiders in the nest cells for offspring, and plugged them with mud, in a case of *Chalybion bengalense*, females added a white layer of unknown material on the outside surface of covers. *Delta esuriens* chose its nesting site beneath the thatched roof of a human house, built a linear series of pot-shaped mud cells that were firmly attached to some rice blades hung loosely beneath the roof, and provisioned caterpillars in these nest cells. The latter built a mud nest on the wall of a human house. *Xenorhynchium nitidulum* made a nest cell oblique a 30° angle from the vertical surface of the wall, plastered the outside surface of the cell with tree resin of a certain plant species after completion of the building, and then stored prey of an unknown caterpillar in the cell. The female of *Xenorhynchium nitidulum* sits in the nest cell after provisioning of the first prey to the following morning suggesting that the wasp progressively provisions its nest and the egg is laid before provisioning.

Keywords: Hymenoptera, India, insect behavior, nest cell, nesting site, provisioning.

* Corresponding author.
E-mail address: phong.wasp@gmail.com

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1. Introduction

India is one of the countries that has the highest biodiversity level of insects in the Oriental region, as well as in the world. For only Hymenoptera, approximately 10,605 species are known from India [1]. Kumar *et al*., [2] reported a total of 189 valid potter wasps of Eumeninae (Vespidae) from India. Because of the high diversity of Hymenoptera, studies of its nesting behavior and biology have, therefore, received a large consideration from entomologists [3-6].

Chalybion bengalense (Dahlbom) has the largest distribution in all species of the genus *Chalybion*, occurring in all regions of the world, except the Neotropical Region [7, 8]. In India, the species is very common. The sphecid takes the nesting behavior using old nests of other wasps, pre-existing holes, and trap nests to be common in *Chalybion.* Nesting habits and biology of *C. bengalense* in India have been studied by some authors such as Jayakar and Spurway [9-11], Jayakar and Mangipudi [12], Chakrabarti [13, 14], Sudheendrakumar and Narendran [15, 16]. However, only Jayakar and Spurway [9], Chakrabarti [14], and Sudheendrakumar and Narendran [15] show its nesting sites in old nests of other wasps and pre-existing holes that are made by other insect species.

Trypoxylon petiolatum F. Smith is one of the wasps of the genus *Trypoxylon* widely distributed in the Oriental region. It is also recorded in both the Palearctic region (China partly, Korea, Japan, and Spain) and Hawaii islands [17, 18]. The nesting habits of the wasp have been studied by a large number of authors such as Horne [3], Rudow [6], and Richards [19] in India (as *Trypoxylon rejector* F. Smith); Barthélémy [20, 21] in Hong Kong; Ma [22] in China (as *Trypoxylon obsonator* (F. Smith); Yasumatsu [23], Nambu [24, 25], and Tsuneki [26] in Japan (as *Trypoxylon obsonator* F. Smith); and Vicent *et al.*, [18] in Spain. These authors record that the wasp uses old mud nests of other wasps and trap nests.

Delta esuriens (Fabricius) is one of the species in the genus *Delta* distributed rather widely and mainly in the Oriental region. The nesting behavior and biology of the eumenine wasp have been studied by several authors. Pham [27] reported only the hunting behavior and prey of the eumenine in Vietnam. Maxwell-Lefroy [28] and Dutt [5] briefly showed the nest structure and the developmental time of immature stages of the wasp (as *Eumenes esuriens* (Fabricius)) in India. The nest consists of 3 or 4 cells and is built in odd places such as corners, walls, rafters, and windows of houses, bamboo, and tree-trunks. The nest cells are ellipse-shaped and stored with paralyzed caterpillars. The wasp takes about 3 hours to build completely a nest cell and also 3 hours to provision prey in a nest cell. The total developmental time from the egg to the adult wasp is about 21 days. Jayakar and Spurway [29] observed nesting activities of the wasp (*Eumenes campaniformis esuriens* (Fabricius) based on 25 nests and indicated that its nests are built in contemporary concrete buildings in Odisha, India. Females carry out 4 steps to build their nests including searching nesting sites, bringing mud and daubing mud to construct nest cells, plugging cell entrances, and plastering mud on completely provisioned nest cells. Eggs are laid before provisioning, often in the morning after the mother carefully checks the nest cells. The total developmental time from the egg to emerge in the adult wasp is 17 to 25 days for males and varies from 19 to 30 days for females. The sex ratio and birth order in each nest are varied and follow no rule orders, respectively. Yamane [30] briefly reported that *D. esuriens* (as the subspecies *Delta esuriens okinawae* Giordani Soika) in Japan builds its pot nests on depressed parts of rock surfaces. The pot is hemispherical and its bottom is widely attached to the substratum. Krombein [31] studied the eumenine (as *Delta campaniforme esuriens* (Fabricius) in Sri Lanka and showed that its nest is built on a wall of a bungalow and includes a row of eight cells in a space of 10.5 cm. The tops of the pots were

more or less obscured by mud that had been plastered over them after construction.

Xenorhynchium nitidulum (Fabricius) is known as a primitively social wasp and is a common wasp in India [32, 33]. The species is known in the Oriya language as "lakha bhanra" (the lacquer bee) [34]. Its nesting habits and biology in India have been studied by many authors. Horne [3] showed only the nesting structure that consists of several cells attached together and a material layer of tree resin covered on the outer surface of nest cells. Wroughton [4], Dutt [5], and Srinivasan and Kumar [35] very briefly showed nesting sites, the nesting structure, and provisioning. West-Eberhard [34] and Spurway [36] produced studies on nesting habits and biology in detail. Whereas Dutt [5] recorded that the wasp mass provisions its nest cell, West-Eberhard [34] and Srinivasan and Kumar [35] stated that *X. nitidulum* progressively provisions its nest cell. Spurway [36] showed both types of provisioning behavior, called "mass provisioning" and "progressive provisioning".

In a course of study on Hymenoptera in India during the year 2015, we undertook a field visit to Odisha, a state located in Eastern India. During the visit, we observed the nesting behaviors of a few wasps. Hence, in the present study, we report the nesting behavior of *C. bengalense*, *T. petiolatum*, *D. esuriens*, and *X. nitidulum*.

2. Material and Methods

The sampling was carried out in Odisha state from 23-30 June 2015. Observations and nest collections were carried out at a big temple, a human thatch house, and a flat roof house (Figure 1A -C).

Figure 1. Nesting habitats of four Indian wasps. A. Nesting habitat of *Chalybion bengalense* and *Trypoxylon petiolatum*; B. Nesting habitat of *Delta esuriens*; C. Nesting habitat of *Xenorhynchium nitidulum*.

A total of 16 nests, including 12 of *C. bengalense*, 2 of *T. petiolatum*, 1 of *D. esuriens*, and 1 of *X. nitidulum*, were studied. Nests collected were dissected for measures of nest size and records of nest contents. The nest contents such as eggs + prey, larvae + prey, fully developed larvae, or cocoons were put in glass tubes 5 cm long and 0.8 cm in diameter for rearing under laboratory conditions. Adult wasps of *C. bengalense*, *T. petiolatum*, and *X. nitidulum* were collected with sweeping nets and killed with a killing jar charged with ethyl acetate. Next, they were pinned, dried, and mounted to be identified. Literature of Kumar *et al.*, [2], Krombein [31], Van der Vecht [32], Kumar and Kishore [33], Bohart and Menke [37], Tsuneki [38], and Hensen [39] were used to accomplish identifications to all taxa. Pictures were taken both in the field and the laboratory using a Canon SD3500IS camera, in Japan.

Voucher specimens of all wasps examined in the present study are deposited at the Zoological Survey of India, Kolkata, India.

3. Results and Discussion

3.1. Chalybion bengalense (Dahlbom)

Chalybion bengalense reused old mud nests of *D. esuriens* (Fabricius) (n = 2) and *Sceliphron madraspatanum* (Fabricius) (n = 7) (Figure 2A) which were built in the majority of observation cases on walls of abandoned houses and in some cases on walls of human inhabiting houses. The sphecid wasp utilized man-made holes (n = 3) on the walls of a big temple built with laterite rocks (Figure 1A, 2B). These holes, regular quadrilateral prisms, were about 1.5 cm high and 1 cm in length of a side, and about
1.2−3.3 m from the ground. The wasp instantly used the holes as nesting sites without the addition of mud on their inside surface and the bottom end. In a case, a female of *C. bengalense*, before building nest cells, carefully probed them, entering for about 5-10 seconds, backing and standing at cell entrances (Figure 2B) for about 15 seconds, and then reentering, sometimes flying away for several minutes. She repeated such actions for 3−5 times (n = 5) and then flew for prey. Females of *C. bengalense* used mud to plug the cell entrance and then covered a layer of white material on the outside surface of the mud plug (Figure 2A, B). The plug varied from 1.5−2.2 mm in thickness and the white material layer was about 0.5 mm thick. The sphecid wasp stored 12 -19 spiders (n=5) in its nest cells. Five nests were collected, two containing dead spiders without eggs, larvae, or pupae and three containing larvae and paralyzed fresh spiders. These larvae failed to pupate possibly because of rearing conditions in the laboratory.

In the present study, *C. bengalense* that nested in artificial holes is reported for the first time from India. Recently, Pham [40] has recorded its nesting sites such as old nests of *S. madraspatanum*, *Sceliphron deforme* (Smith), *D. esuriens*, *Rhynchium brunneum* (Fabricius), *Eumenes architectus* Smith and *Phimenes flavopictum continentale* (Zimmermann); pre-existing holes (screw recesses and holes of wood worms); hollow bamboo stems and trap nests in Vietnam. In our unpublished data collected on 21st September 2023 at Uong Bi city, Quang Ninh province, the wasp utilized an old mud nest of a pompilid wasp (*Auplopus* sp.), which was built on the ground. Therefore, it is judged that the sphecid wasp *C. bengalense* takes a large variation of nesting sites.

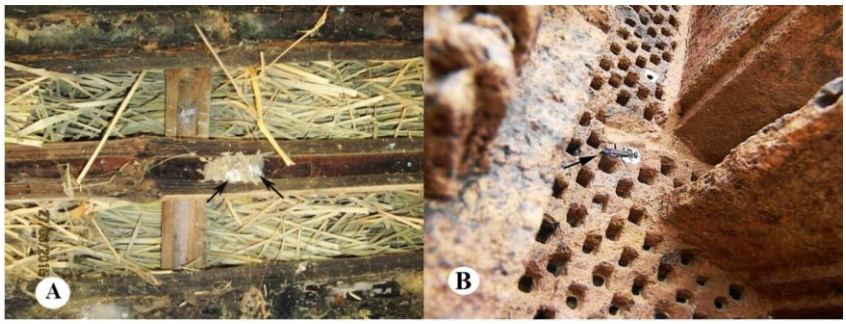

Figure 2. A−B. Nesting sites of *Chalybion bengalense*. A. Old nest of *Sceliphron madraspatanum*; B. Man-made hole on a wall of a big temple. Arrows show the nesting sites, white nest plugs and an adult female closing its nest cell.

3.2. Trypoxylon petiolatum F. Smith

We observed two females of this crabronid wasp utilizing man-made holes on the outside surface of the walls of the temple as described above. Nesting sites were more than 3 m from the ground. We did not know whether *T. petiolatum* intactly used or added mud in the holes because no nests were collected and dissected for rearing at the time of the study. In one case, a female was found bringing a spider

under her body in flight. She landed at the nest entrance, immediately entered into her nest, stayed in for about 10 seconds, then appeared and stood at the nest entrance for about 7 seconds, and then left its nest. The species covered the holes with mud. In one case, we observed a female bringing pieces of mud with her mandibles in flight. She landed and put mud pieces at the nest entrance, beginning at its lower part. Mud pieces were stretched out by the mandibles until the nest entrance was completely closed. The wasp used about 8 mud pieces to cover it. Mud plugs were at the same level as the surface of the holes.

Preceding studies [3, 6, 18-26] showed *T. petiolatum* using old mud nests of other wasps and trap nests. In the present study, *T. petiolatum* using man-made holes for the nesting site is recorded for the first time.

In *Trypoxylon*, two nesting habits are well known, namely "nest-renting" and "nest-building". In the first case, wasps that take this nesting behavior are called nest-renting ones and in the latter, they are called pipe-organ mud dauber wasps [37]. Whereas several species of the genus take both these habits, for example, *Trypoxylon politum* in North America [41], *T. petiolatum* takes only a single behaviour "nest-renting".

3.3. Delta esuriens (Fabricius)

A nest of *D. esuriens* was found and collected in a human thatch house (Figure 3A). The nesting site was beneath the eaves, about 3 m from the ground. The nest was glued to some rice blades hung loosely beneath the roof.

It was dissected on the same day of the collection and consisted of nine cells. Of these nine cells, one at the bottom end consisted of a dead adult wasp, another at the bottom end, and three at the middle area were parasitized by two certain parasites because they had emerged and escaped from the cells with open holes that were different from their hole diameters, other two at the middle area consisted of died caterpillars and possibly eggs or larvae that had been failed in these cells, one at the subapical end consisted of a died adult wasp of unknown reasons and one at the apical end consisted of two died caterpillars with its opened cell entrance. The cells, about 1.2-1.4 cm in diameter at the base and 1-1.2 cm high, were pot-shaped and smooth on the inner surface and rough on the outer surface (Figure 3B). The cell wall was about 1 mm thick. The cells were built together and no mud layer was covered on their outer surface.

Compared to preceding studies [5, 27-31], *D. esuriens* builds its nest on rice blades hung loosely beneath the roof to be a new nesting site reported for the species. Because of such a nesting site, the nest shape (like a round lump of mud) of the wasp is different from that reported in preceding studies (like a flat piece of mud).

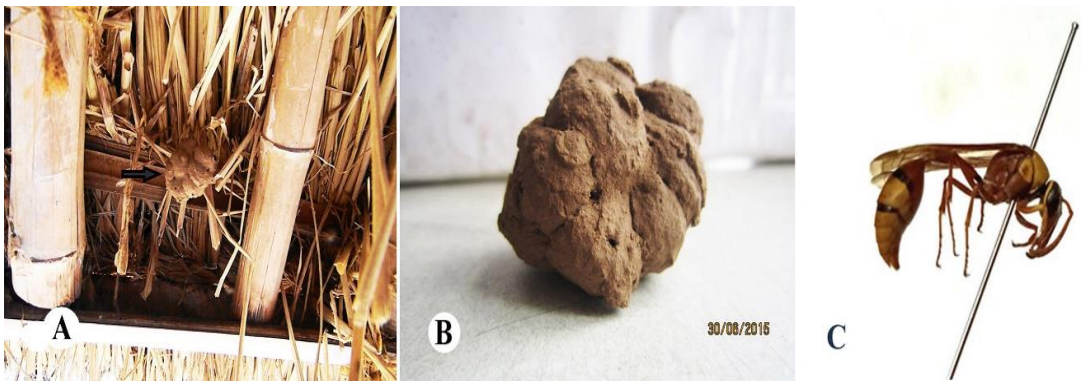

Figure 3. A–C. Nesting site, nest, and adult of *Delta esuriens.*
A. Nesting site beneath the eaves of a human thatch house; B. Nest like a lump of mud;
C. Adult female collected in the nest. The arrow shows a site in which the nest is built.

3.4. Xenorhynchium nitidulum (Fabricius)

A female of *X. nitidulum* was found building its nest on a wall of a Buddha altar room of a human house at 8.45 am on 26th June 2015. The door of this room was usually closed and therefore the room was rather dark. The female flew into and out of the room through a door transom (Figure 1C). At the time of observation, the wasp was building about half of the first nest cell. The nesting site was about 2.2 m from the floor. The eumenine wasp brought spherical pieces of wet mud with her mouth in flight, clamping them with the mandibles. It took about four minutes each time to bring mud. The mud chosen to construct the nest was fine-grained soil. After completely building this nest cell, the wasp used a resinous material of a certain plant to plaster on the outside of the nest cell (Figure 4A). Sometimes during the resin-bringing process, she dropped several pieces of the resin on the wall (Figure 4A, B). She was often absent from the nest for many minutes because she possibly flew to flowers for food. The nest cell was completed at 10.57 am and the wasp was in it for many minutes before flying away for hunting. This may be suggested that *X. nitidulum* lays an egg before provisioning. The nest cell, barrel-shaped, was about 19 mm long and 9 mm in diameter measured in the middle and smooth on the inside surface and rough on the outside surface. The cell entrance was upwards and approximately 5.7 mm in diameter. The cell wall was about 0.8 mm thick. About the third of the cell base was attached to the vertical surface of the wall and the nest cell, therefore, was oblique at an angle of 30° from the wall (Figure 4B). The wasp returned to its nest at 11.23 am with a caterpillar of unknown lepidopterous species, swiftly entered, head first, put it and then backed away, and flew away. She brought prey with her mouth and it took about 40 seconds for her to put the prey in the nest cell. During the afternoon the wasp sat in the nest (Figure 4B), sometime it was away for possibly food. In the evening, she slept within this nest, heading forward the cell entrance. In the following morning, the wasp left the nest after about 7.00 am.

In this study, we observed the wasp staying in her nest cell after putting the first caterpillar during the afternoon suggesting that *X. nitidulum* takes the progressively provisioning behavior. One of the common nesting behaviors of the wasp is the use of tree resin to cover the nest cell suggesting that this is to protect the nest from predators, for example, the chrysidid wasp *Stilbum cyanurum* (Forster) [34]. The nesting behavior of tree resin-using species is also reported for several species not only of megachilid and apid bees but also of sphecid and crabronid wasps [42, 43].

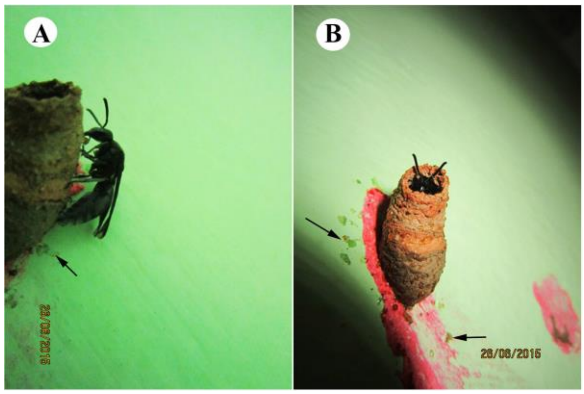

Figure 4A−B. Nesting activity and nesting site of *Xenorhynchium nitidulum*. A. Female plastering the outside of nest cell with resinous plant; B. Nest attached to the vertical surface of the wall and the female sitting in the nest cell. Arrows show pieces of the resinous plant on the wall.

An interesting point in this eumenine wasp is that it attacks nest intruders by stinging. Because of such nest-defensive behavior, West-Eberhard [34] revealed that *X. nitidulum* females sit curved in the shape of a letter "C" in their nest cells so that both head and abdomen point outward at the mouth of the cell. When approached, the head is slightly retracted, and the abdomen thrusts forward to sting. However, our observations do not record this sitting position, but only the head outwards the cell entrance. Possibly only in the case of the nest defense, the wasp takes such a sitting position and defensive stinging of *X. nitidulum* is necessary to be studied further because, up to date, no publications have recorded this behavior in any Eumeninae.

4. Conclusion

The nesting behavior of four Indian wasps *Chalybion bengalense* (Dahlbom) (Sphecidae), *Trypoxylon petiolatum* F. Smith (Crabronidae), *Delta esuriens* (Fabricius), and *Xenorhynchium nitidulum* (Fabricius) (both, Vespidae: Eumeninae) is observed and described. All four species nest on man-built sites or in old mud nests of other solitary wasps in the case of *C. bengalense*. New nesting sites in artificial holes and beneath the roof are recorded for the first two species and the third, respectively.

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