



RESEARCH ARTICLE - BEES

Nest architecture and life cycle of Small Carpenter bee, *Ceratina binghami* Cockerell (Xylocopinae: Apidae: Hymenoptera)

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Abstract

The small carpenter bee, *Ceratina binghami* (Xylocopinae: Apidae) is an important pollinator of many agricultural and horticultural crops. The nests constructed by the bee in the pruned pithy stems of *Caesalpinia pulcherrima* were collected to study its biology under laboratory conditions. The bee constructs its nest in the pithy stems of different plants by chewing out the pith. The bee is polylectic and provision with pollen balls to its brood cells with an interesting nest guarding behavior. The nests consisted of egg, larvae, prepupae, pupae and adult stages. Life cycle of the bee was completed in 41.67 ± 3.12 days. Pupal stage consisted of different colors of eye pigmentation. Foraging activity of the bee started during morning hours approximately between 6.45 to 7.15 am and ended during the late evening hours of 4.50 to 5.15 pm. Detailed nest architecture of the bee was studied. The nesting behavior and short life cycle of *C. binghami* in pithy stems of *C. pulcherrima* helps in the *in-situ* conservation and utilization of these bees in the pollination of agricultural crops.

Introduction

Small carpenter bees of the genus *Ceratina* Latreille, are a widespread bee fauna belonging to the subfamily Xylocopinae. They are bright metallic blue to green bees actively foraging on wide range of crops plants (Michener, 2007). *Ceratina binghami* Cockerell (1908) is polylectic and were reported to be an efficient pollinator of wide range of crops temperate fruits and oilseed crops such as niger, safflower, mustard, linseed (Navatha & Sreedevi, 2015), apple, raspberry, cranberry, cosmos, sunflower, red gram, tomato, winged bean, mustard, alfalfa (Mattu & Kumar, 2016). Native bee communities serve as a needed alternative in the event of honey bee declines and may contribute substantially to crop pollination (Parker et al., 1987).

Ceratina bees construct their nests in dead woods and pruned pithy stems by making linear burrows (Raju & Rao, 2006). Adult female bee chew opens the central pith of the

pruned stem and construct cells. Then the female flies out, forage for the pollen, mould them into pollen balls and place them inside the cells (McIntosh, 1996). On this pollen ball provision, she lays the egg. After provisioning, few species of bees cap the nest entrance with a membranous layer using the chewed pith and leave the nest. But in few other species, females were found to remain in their nests, guarding their broods till they complete development (Sakagami & Maeta, 1977). The nesting biology of several species of *Ceratina* viz., *C. smaragdula* (Kapil & Kumar, 1969; Batra, 1976b) and *C. calcarata* (Rehan et al., 2010) was well documented and could be easily conserved *in-situ* using pithy stems of different plants in different habitats.

Destruction of natural nesting habitats of these native bees will have a direct negative impact on the valuable pollination provided by them. The decreasing abundance and species richness of native bees in agricultural landscapes due to habitat loss and lack of foraging resources was well



reported (Kevan, 1999; Ricketts, 2004). Understanding of nesting behavior and life cycle will enable us to conserve the bees and utilize them for efficient pollination in different crops. The present investigation on *C. binghami*, an efficient crop pollinator was undertaken to study its life cycle and nest architecture.

Materials and Methods

Study Location

The study was carried out in the experimental farm of ICAR-National Bureau of Agricultural Insect Resources (NBAIR) Bangalore-Yelahanka Campus (13.096792N, 77.565976E). The stems of five-year-old Peacock flower, *Caesalpinia pulcherrima* (Fabaceae) were pruned as a standard practice to enhance the branching and flowering of the plant during the first fortnight of September 2016. The cut ends of the stems were the site of attraction for the bees for nest building (Fig 1) and were regularly monitored for the presence of nests constructed by the *Ceratina* bees.

Nest architecture and Biology of *Ceratina binghami*

The nest construction by the bees were identified by the presence of holes at the cut ends of the pruned stems in few cases and by the sighting the bees entering the holes in some places. Twenty-five nests were destructively sampled from the *C. pulcherrima* plants located adjacent to the two parcels of farmland. The nests were collected during the evening hours to ensure the presence of adult bees in the nest after foraging during the day. The entrance hole of the nests was closed with a piece of cotton and tied with a rubber band to prevent the escape of the adult bees present inside the nest. The nests were cut opened carefully starting from the entrance hole giving a gentle split lengthwise using a sharp knife. Once after making the linear split of the nest, the nest architecture including the nest length, brood cell length and brood cell breadth were measured and recorded. The number of immature stages, presence of pollen provisions, length and breadth of pollen provision were recorded. After examination, the two split stems were joined together with a rubber band to

provide suitable micro-climate for the broods to develop and mature. The immature stages in the nest were reared till adult emergence in the laboratory (28 ± 1 °C; 70% RH). The stems were kept inside the rearing boxes covered with a cotton cloth to provide aeration. The split stems were opened on regular basis to examine any change in the life stage of the bee. The duration of the different life stages of the bee viz., egg, larvae, pupae, adult and adult longevity was also recorded.

Classification of nests based on brood components

The nests were classified into five categories viz., hibernacula nests, founding nests, active brood nests, full brood nests and mature brood nests as per the descriptions by Daly (1966) based on the life stages of the bees present in the cells. **Hibernacula nests** include the nests that were built during the previous season with their interior content filled with fecal remains, pollen and molted skins of previous broods. **Founding nests** have only few cells with usually harboring adult bees actively involved in constructing cells with partitions. These cells are devoid of pollen masses and immature stages of the bees. **Active brood nests** contain pollen masses in all the formed cells with few immature stages of the bees. **Full brood nests** inhabit the life stages of the bee at different stages of development with pollen masses of different proportions due to active feeding of the larvae. **Mature brood nests** were found not to inhabit either pollen masses or immature stages of the bees. They contain only the fecal pellets, pupal exuviae and chewed up walls of the cells indicating the emergence and exit of the adult bees.

Foraging behavior of *Ceratina binghami*

The period of activity of the *Ceratina* bees were observed and recorded in the study site. Five prior marked nests were observed for a period of 10 days. The nests were inspected during early morning hours for the presence of adult bees. The time when the adult bee leaves the nest for foraging was noted down. The time spent by the bee in the nest back from foraging activity was also recorded. Under field conditions, flowers visited by the bees, the reward collected and the average time spent by the bees in individual flower was also recorded.

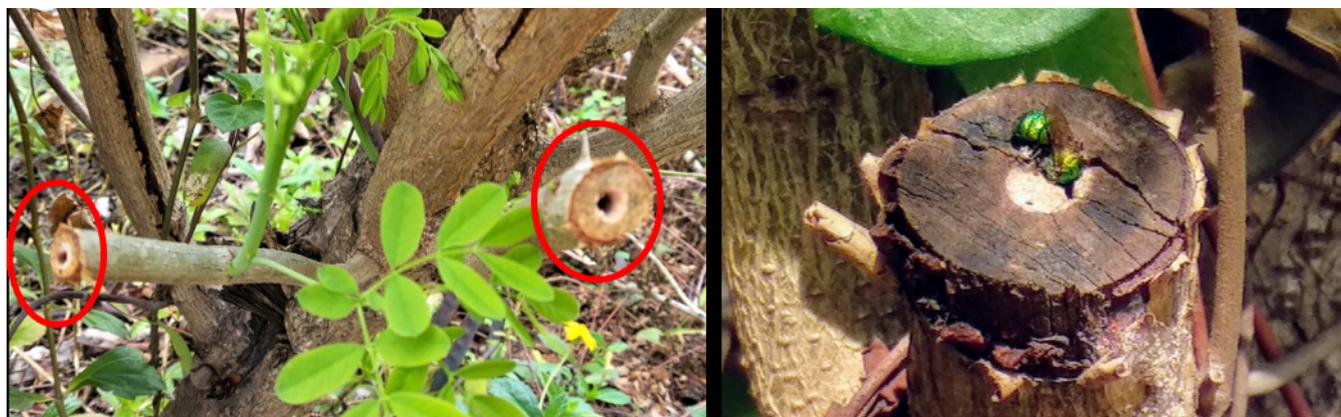


Fig 1. Pruned cut ends of *Caesalpinia pulcherrima* with *Ceratina binghami* showing nest building behavior.

Results

Lifecycle of *Ceratina binghami*

A total of twenty five nests were collected comprising of following categories. Six of them were active brood nests with a solitary mother were found along with the developing brood. Eight were founding nests with clear interior walls found with signs of progressive cell construction by the adult female bee. Five nests were of mature brood nests (Fig 2) in nature with no pollen mass and inhabit only with late larval instars, pre-pupae, pupae and adults (in different stages of pigmentation) in the cells. Four nests were of full brood nests with the pollen masses of different sizes with different stages of the larvae inside the cells.



Fig 2. Full brood nest and pollen provision made by *Ceratina binghami* in pithy stems of *Caesalpinia pulcherrima*.

The life cycle of *C. binghami* consisted of egg, larvae, pupae and adult stages (Table 1). The adult females laid single egg over the pollen provision in individual cells. The pollen provisions were yellowish brown in colour, slightly viscous, soft and ranged between 0.8 to 0.9 cm in length ($n = 25$). The egg appeared to be spindle shaped, translucent white in color, placed dorsally over the top of the pollen ball to ensure the immediate availability of food for the hatching larvae (Fig 2). The apodous larvae were found to feed actively over the pollen mass in each cell. The pollen mass was found to be bigger in size in the cells containing the early instar larvae and vice versa in the case of mature larvae. This may be due to depletion of the nutritious pollen fed by the growing larvae.

Table 1. Life cycle of *Ceratina binghami*.

| Life stage | Life stage description | Duration (days) (N=25) |
|--------------|----------------------------------|------------------------|
| Egg | - | 4.83±0.75 |
| | One fifth of size of pollen ball | 3.00±0.89 |
| | Twice the size of pollen ball | 3.67±0.52 |
| Larvae | small bit of pollen | 3.33±0.52 |
| | Fully grown larvae | 3.17±0.98 |
| | Total larval period | 13.67±1.63 |
| Prepupae | - | 4.50±0.54 |
| | White eyed | 2.67±0.81 |
| | Pale brown eyed | 1.67±0.52 |
| Pupae | Dark brown eyed | 2.17±0.40 |
| | Black eyed | 3.67±0.81 |
| | Total pupal period | 10.50±2.07 |
| Adult | 1/2 body pigmented | 1.17±0.41 |
| | 1/4 body pigmented | 1.50±0.55 |
| | 3/4 body pigmented | 1.33±0.52 |
| | Full body pigmented | 3.50±1.51 |
| | Total adult period | 7.67±1.50 |
| Egg to Adult | - | 41.67± 3.12 |

The larvae required 13.67 ± 1.63 days ($n = 25$) to complete its development. Pre-pupae metamorphose into white eyed pupae, later the eye color changed into pale brown, dark brown and then black in color (Fig 3). The duration of the pupal stage lasted for 10.5 ± 2.07 days ($n = 25$) with changing eye pigmentation from lighter to dark at different levels. After reaching the black-eyed stage of the pupae, the body the bee gradually attains pigmentation at different stages.

The body color of the adult changed from gradual pigmentation to complete pigmentation (Fig 4), in 3.5 ± 1.51 days. After full pigmentation, the pupae molted into winged adults. The adult bees were found to chew upon the partition layer of the cells to ensure easier emergence from the nest. The total life cycle of *C. binghami* was completed in 41.67 ± 3.12 days.



Fig 3. Pupae of *Ceratina binghami* at different stages of eye colouration.

Nest architecture

Ceratina binghami was found to construct linear nests in inside the cut ends of the pithy stems of *Caesalpinia pulcherrima* (L.) (Fabaceae) plants. When the nests were dissected, adult females were found to stay in a defensive position with their head or abdomen in some nests facing upwards guarding the brood cells. All the completed nests were found to harbor adult female bees guarding the nest entrance (Fig 1). In few of the nests, the adult females were observed near the septa of the second or third cells. They were observed to repair the broken septa during the brood development. The nests were unbranched with average length of 8.04 ± 1.93 cm ($n = 25$). The pith of the stem was used by the bees to form the cell partition, the depth of which was recorded to be 0.57 ± 0.06 cm respectively. Out of the twenty-five nests sampled, all the nests were found to harbor different life stages of the bees. None of the nests were either found to be orphaned (without

adults) or attacked by any parasitoids. The diameter of the nest entrance hole was found to be 1.26 ± 0.11 cm wide. Each nest was found to contain 6-7 cells with an average with a length and breadth of 1.0cm and 1.0cm respectively.

Foraging behavior

Ceratina bees were found to visit many species of flowering plant species and hence are polylectic in habit. Among cultivated crops, the bees were found foraging on flowers of winged bean, tomato, pigeon pea, corn and sunnhemp. On an average, the bees spent 21.4 seconds in individual flower. The bees were found to collect pollen reward back to the nest. The pollen laden bee entered the nest through the entrance hole and spent approximately 14.8 seconds inside the nest and then started the next foraging bout. Foraging started during the morning hours between a time period of 6.45 to 7.15 am and ended during the late evening hours of 4.50 to 5.15 pm.



Fig 4. Adult of *Ceratina binghami* at different stages of body pigmentation.

Discussion

In the present study, *C. binghami* preferred the pithy stems of *Caesalpinia pulcherrima* but we have also noticed its nesting activity in other plants like *Adhathoda zeylanica* and *Adenanthera pavonina*. The lifecycle, nest site selection and nest architecture vary between the species, climate, availability of plants and various other factors. Ali et al. (2016) reported that *Ceratina (Pithitis) smaragdula* made its nests in wooden stalks of Ravenna grass (*Saccharum ravennae* L., *Poaceae*), with their life cycle completed between 28 to 32 days under laboratory conditions in Pakistan. Adult females were found to guard the nest entrance with their head facing upwards in few nests and with their abdomen in other few nests. The adult bees were found crawling over the brood cells in few nests during the dissection. This might be due to the examination of the provisioned pollen provided by the females in the individual cells for the brood development. The sub social behavior of female bees crawling through the cell partitions in the nest to examine the offspring was reported by Maeta et al., 1997.

The nest guarding behavior in a completely provisioned nest by an adult female is advantage for the offspring as it can increase the offspring survival by protecting from the natural

enemies. The dissected nests showed 100% emergence of adult bees without any signs of parasitization which might be due to the parental care provided by the adult bee as exhibited by their guarding behavior. Increased offspring survival as a result of guarding strategy by adult females of *C. cucurbitina* was reported by Mikat et al., 2016. *Ceratina calcarata* was observed to be a sub-social species whose females build their nests solitarily but remain in the nest and continue to care for their offspring till they reach adulthood (Durant et al., 2015). Rehan and Richards (2010) reported the similar trend in the nesting biology of *C. calcarata* with duration of 46 days to complete single generation.

All the inspected nests were found to inhabit different life stages of the bees. In some nests, empty cells were found between the cells with life stages of the bees. Few broods might have completed their development and emerged out of the nests leaving their cells empty amidst the other cells. Those empty cells were found to possess eaten up cell partitions with molted exuviae in the cells as evident of their emergence. The pupae were found near the entrance in most of the nests. The results were in line with the observations made by Yogi (2014) who reported the orientation of the pupae of *C. simillima* towards the entrance of the nest. In his study, *C.*

simillima was found to utilize *Caesalpinia* stems as nesting site. Hongjamrassilp and Warrit (2014) reported the similar nest architecture of a candidate bee *Xylocopa nasalis* belonging to the subfamily Xylocopinae with linear unbranched nest with pithy partitions made by the founding female.

Conclusion

In conclusion, the nest architecture and life cycle details provided in this study will be of immense importance to melittologists involved in trapping and conservation of *Ceratina* bees. Pithy stems of the *Caesalpinia* can be used to conserve these bees by serving as the artificial nesting substrates for the bees for their valuable ecosystem service in terms of crop pollination. Farmers can be encouraged to provide artificial nesting substrates using the pithy stems of *C. pulcherrima* to conserve these bees or by growing these plants as hedges in the farms and periodical pruning not only helps in conservation of the bees and enhanced farm scaping.

Author's Contribution

The first author carried out the field visits and studied the nest architecture and nesting biology of the bee. The second author conceived of the study and participated in design and coordination. Both the authors read and approved the final manuscript.

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