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Ecological notes on a plant ant, *Cladomyrma scopulosa* Eguchi & Bui (Hymenoptera, Formicidae, Formicinae) associating with a tree species *Saraca dives* Pierre (Leguminosae)

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Abstract. In north and north-central Vietnam colony structure and other aspects of biology of *Cladomyrma scopulosa* Eguchi & Bui associating with a tree species *Saraca dives* Pierre were recorded. Within the genus *Cladomyrma* a colony structure with multiple dealate queens has been seen almost exclusively in *C. scopulosa*. Our limited observations suggest that secondary polygyny at the early founding stage, or even primary polygyny, often occur in *C. scopulosa*. The colony may become progressively more polygynous by accepting supplementary queens. Genetic relatedness among dealate queens, however, was not estimated in the present study.

Keywords: *Cladomyrma scopulosa*, *Saraca dives*, colony structure, Vietnam

INTRODUCTION

The members of the genus *Cladomyrma*, belonging to the tribe Lasiini of the subfamily Formicinae (Bolton 2003), are known as plant ants associating with various taxa of vascular plants (Maschwitz *et al.* 1991; Moog *et al.* 1998, 2005; Agosti *et al.* 1999). Agosti *et al.* (1999) revised the genus and recognized eleven species whose range was strictly confined to the western part of the Malesian floristic region, comprising the Malay Peninsula (northern limit: the Kra Isthmus), Borneo and Sumatra. However, recently an undetermined species of the genus was reported from north Vietnam by Yamane *et al.* (2003) and another undetermined species from east Thailand by Fujiwara *et al.* (2004). Eguchi & Bui (2006) found many colonies of a *Cladomyrma* species inside shoots and branches of a tree species, *Saraca dives* Pierre (Leguminosae), in Cuc Phuong north Vietnam and described the species as *Cladomyrma scopulosa* Eguchi & Bui. This species is probably a close relative of *C. petalae* Agosti known from the Malay Peninsula which inhabits a range of host plants which are mostly unrelated but include *Saraca thaipingensis* Cantley ex Prain. We here report on colony structure and other aspects of biology of *C. scopulosa* revealed by our field surveys in north and north-central Vietnam.

STUDY SITES

The present study was conducted in two famous national parks (NP) of Vietnam, Cuc Phuong NP and Pu Mat NP.

Cuc Phuong NP (CPNP) occupies parts of Ninh Binh, Hoa Binh and Thanh Hoa Provinces in north Vietnam (20°14–24'N, 105°29–44'E, 22.2 km^2).

The area is dominated by limestone forest. Yamane *et al.* (2003) recorded 160 ant species belonging to 50 genera in eight subfamilies (or 11 subfamilies according to the revision of Bolton, 2003).

Pu Mat NP (PMNP) is situated on the eastern flanks of the Truong Son mountain range (18°46'–19°12'N, 104°24–56'E, 91.1 km^2), and belongs to Nghe An Province, north-central Vietnam. Elevation in the national park ranges between 100 and 1,841 m, although 90% is under 1,000 m in elevation. The most widespread vegetation type in the national park is lowland evergreen forest. No myrmecological survey had previously been conducted here.

MATERIALS AND METHODS

Saraca dives, the only known host plant of *Cladomyrma scopulosa*, is a tree species (5–20 m in height) of the family Leguminosae (according to some botanists, Fabaceae or Caesalpiniaceae). The species occurs in the northeastern part of the Continental Southeast Asiatic floristic region (SE Yunnan, and SW, S and SE Guangxi, China; Vietnam; Laos), and is common in river or stream side forests from 200 to 1,000 m alt. (Wu *et al.* 1988).

In order to record colony structure and other aspects of biology, we conducted the following surveys.

"Survey 1" was carried out in the central part of CPNP in mid-June 2005. We walked along a trail and chose 20 *Saraca dives* trees encountered. In order to find colonies of *C. scopulosa* and the other guest ants we carefully observed main branches and the trunk of young trees (up to 3 m in height), and one to several large branches at or near the base of developed (tall) trees. We found colonies at the ergonomic or reproductive stage by shaking branches and trunks (if a colony is present, a lot of workers come out), and carefully opened them and sampled the representatives of all castes, subcastes, sexes and immatures of guest ants, myrmecophiles and other biotic remains inside tunnels. We found colonies at the founding stage by dissecting several terminal branches for each tree, and sampled them in the same manner. Although colonies at the ergonomic or reproductive stage seem to occupy many different branches of a single tree (i.e. polydomy), in Survey 1 we treated ants from a single branch as a colony (i.e. satellite nests of a single colony may often have been treated as different colonies).

Survey 2 was carried out at Khe Kem Area of PMNP in mid-March 2006. We cut off one piece of branch (500 mm in length) occupied by *Cladomyrma* ants from each of 15 trees (i.e. 15 branches in total). In Survey 2 we paid heed to sampling representative guest ants, myrmecophiles and other biotic remains from each continuous tunnel (in the case where three discontinuous tunnels were bored inside a branch, these were considered separate samples, like "Tunnel No. 1 of Branch K").

Field observations and casual sampling in the two study areas supplemented the above-mentioned surveys.

Terms used for the colony stages basically followed Hölldobler & Wilson (1990), but we define the early founding stage as the colony stage in which the first brood is raised but no adult worker has yet emerged. When multiple queens found a colony together, the condition is referred to as primary polygyny. When supplementary queens are added after colony foundation, the condition is referred to as secondary polygyny. However, as we did not observe the condition of the ovaries and spermatheca of dealate queens, we could not confirm whether the queens had contributed to reproduction: the definition of polygyny *sensu* Hölldobler & Wilson (1990).

RESULTS

Results from Survey 1

We found nine *Saraca dives* trees colonised by *Cladomyrma scopulosa*: 14 living colonies and a nest chamber including a living dealate queen which had not yet raised the first brood (BTV16vi05-01). On the remaining 11 trees we did not find colonisation by *C. scopulosa* from the branches within reach. Both young and developed

trees were occupied by relatively well-developed colonies (ergonomic or reproductive stage). Five colonies (BTV16vi05-07, -09, -19, -20, -25) included male pupae, i.e. were at the reproductive stage. Two colonies (BTV16vi05-02, -06) were in the early founding stage and monogynous. Colony BTV16vi05-20 (a well-developed colony) included three dealate queens. Since the branches located high in the canopy (>3 m) were not examined and some initial colonies might have been overlooked due to the sampling protocol, the colonization rate (45% including BTV16vi05-01) was possibly an underestimate. We found five nest chambers containing a dead dealate queen (but no remains of workers). Colonies were mostly accompanied by pseudococcids and, in one case, coccids. Undetermined dipteran larvae were also found in the nest of the colony BTV16vi05-21 (Fig. 6).

In addition to *C. scopulosa*, the following ant species nested inside shoots of *Saraca dives*: *Tetraponera* sp. (cf. *nigra* (Jerdon)) (two colonies at the early founding stage); *Cataulacus granulatus* (Latreille) (one colony at ergonomic or reproductive stage); *Vombisidris* sp. (*Vombisidris* sp. 3 of Seiki Yamane) (one colony at ergonomic or reproductive stage) and *Camponotus* (*Colobopsis*) sp. (*Camponotus* sp. 136 of Sk. Yamane) (one colony at ergonomic or reproductive stage).

Results from Survey 2

One continuous tunnel or two to three discontinuous tunnels had been bored inside each of the branches sampled. Of a total of 27 tunnels three had no ants and one was occupied by *Crematogaster* sp. The remainder, i.e. 23 tunnels, were occupied by *Cladomyrma scopulosa* (Tunnel No. 2 of Branch K contained a lot of dead workers and males only) (Table 1).

Diameter of the tunnels occupied by *C. scopulosa* ranged from 1.5 to 4 mm. The number of dealate queens found in each tunnel varied from 0 to 2 (Table 1). One tunnel (No. 1 of Branch G) contained two queens with wing remnants as well as two dealate queens. Fourteen tunnels included males, one to many in number, and four tunnels alate queens, also one to many. Pseudococcids as well as unidentified white particles were regularly found in tunnels occupied by healthy *C. scopulosa* colonies (Table 1; see also Fig. 4 and 5).

In one of the 27 tunnels surveyed (No. 1 of Branch K) we found many larvae of different sizes, and a few adults, of a small fly species (Family Phoridae), on or around a huge number of dead workers and males of *C. scopulosa*. In addition to the phorid species we found an undetermined dipteran larva similar to the larvae found in Survey 1.

Field observations and casual sampling

In Khe Kem Area of PMNP, from a single continuous tunnel of a terminal branch (ca. 300 mm in length), we collected the colony Eg15iii06-08 which included five dealate queens accompanied by a lot of workers and males (Fig. 1).

In Sang Le Forest of PMNP we found a colony (Eg02iv06-01) at the early founding stage in which five dealate queens coexisted (Fig. 2). In the same forest we encountered alate queens flying down to young trees of *Saraca dives* from late morning to early afternoon on 3 April (a sunny day). We observed several queens coming to a nest entrance closed by a claustral founding queen and trying to reopen the entrance by chewing in cooperation (Fig. 3).

DISCUSSION

Colony structure in *Cladomyrma scopulosa*

In the present study sites *C. scopulosa* frequently nested in shoots and branches of *Saraca dives*, while five other ant species were found occasionally. These, probably excluding the two initial colonies of *Tetraponera* sp. (cf. *nigra*), seem to occupy the tunnels originally made by *C. scopulosa* (having either actively evicted the original colonies or colonised after they had left) (see Moog & Maschwitz 2000). Two colonies of

C. scopulosa (one from casual sampling and one from Survey 1) included multiple dealate queens, but unfortunately we did not pay attention to confirming the continuity of the tunnel(s) when sampling them. Thus we cannot exclude the possibility that the multiple dealate queens belonged to the different colonies neighbouring each other. However, in Survey 2, we found three continuous tunnels each occupied by a well-developed colony with at least two dealate queens (Table 1). In the casual sampling in PMNP we found a fragment of a well-developed colony with five dealate queens from a single continuous 300-mm tunnel (Eg15iii06-08). These observations provide strong evidence that colonies with multiple dealate queens are not rare in *C. scopulosa.* The density of dealate queens in a terminal branch (five per 300-mm tunnel) indicates that the colony as a whole may include a lot of dealate queens. This is in contrast to the other members of the genus where colonies with multiple dealate queens are absent or rare (see Agosti *et al.* 1999); *Cladomyrma petalae*, a possible close relative of *C. scopulosa* (Eguchi & Bui 2006) and associated with *Saraca thaipingensis*, is monogynous (J. Moog, pers. comm., December 2005). In the present study we did not confirm whether the dealate queens had contributed to reproduction: the definition of polygyny. We also did not assess genetic relatedness among the dealate queens. However, secondary polygyny may play an important role in the social and demographic structure of *C. scopulosa* colonies.

We observed several queens coming to a nest entrance closed by a claustral founding queen and trying to reopen the entrance by chewing in cooperation. Furthermore, we found a colony (Eg02iv06-01) at the early founding stage in which five dealate queens coexisted (Fig. 3). Whereas Moog & Maschwitz (2000) mentioned the chasing-off or death of at least one of the combatants on such occasions in *C. petalae*, our observations suggest that secondary polygyny at the early founding stage or even primary polygyny often occur in *C. scopulosa* (see also Feldhaar *et al.* (2003) for a discussion of *Crematogaster* sp. 2 on *Macaranga pearsonii* Merr.). The colony may become progressively more polygynous by accepting supplementary queens. Dalecky *et al.* (2005) comprehensively studied polygyny in the plant-ant *Petalomyrmex phylax* Snelling, and concluded that the latitudinal cline in polygyny may result from historical processes such as selection for a more dispersive strategy along a colonization front (i.e. monogyny may have been favoured along the front of the southward expansion of *P. phylax*). Could this also be true in the evolution of the *Cladomyrma scopulosa* - *C. petalae* lineage? Or, are there environmental factors correlated with the degree of polygyny in the lineage in contrast with *P. phylax*? In order to answer such interesting questions, colony structure of *C. scopulosa* should be studied more thoroughly, and carefully compared with that of the other *Cladomyrma* species, especially *C. petalae* associating with *S. thaipingensis*.

Other aspects of biology

Phorid flies have been known as guests of various ants. In ant colonies, phorid larvae are scavengers, parasites/parasitoids of hosts, and/or social parasites fed by hosts (Hölldobler & Wilson 1990). In Survey 2 we found many phorid larvae wriggling on or around a huge number of dead workers and males within a tunnel. Because larvae of different sizes were found we can almost exclude the possibility that they all emerged from hosts for pupation. This suggests the phorid larvae were scavengers of dead ants (killed by sickness?). We cannot suppose what the second undetermined dipteran larvae do inside host colonies.

From March to April 2006 (in PMNP) we found a lot of colonies of *C. scopulosa* including males and alate queens, and observed new queens flying down to *Saraca dives* trees and founding their colonies. In mid-June 2005 (in CPNP) we found several colonies at the founding stage. These suggest that the nuptial flight of *C. scopulosa* probably occurred from mid-March to mid-April in PMNP, and from early May to early June in CPNP.

Figs. 1–6. *Cladomyrma scopulosa*. **1**, colony with multiple dealate queens (Colony: Eg15iii06-08); **2**, a colony at the early founding stage with multiple dealate queens (Eg02iv06-01); **3**, two queens trying to reopen a nest entrance closed by a claustral founding queen; **4**, a major worker and an unidentified white particle (Eg15iii06-08); **5**, a pseudococcid guest (Eg15vi05-15); **6**, a minor worker and an undetermined dipteran larva (BTV16vi05-21).

Table 1. Colony structure of *Cladomyrma scopulosa* (data obtained from "Survey 2").

Branch (n=15)	Tunnel (n=27)	Guest ant	Dealate queen	Worker	Alate queen	Male	Immatures	Myrmecophiles	White particles
A	No. 1	*C. scopulosa*	2	many	absent	many	present	Pseudococcids	present
B	No. 1	*C. scopulosa*	0	many	absent	present	many	Pseudococcids	present
C	No. 1	no guest							
C	No. 2	*C. scopulosa*	0	many	absent	1	present	Pseudococcids	present
D	No. 1	*Crematogaster* sp.	0	many	absent	absent	present	Pseudococcids	absent
D	No. 2	*C. scopulosa*	0	many	many	some	absent	Pseudococcids	present
E	No. 1	no guest							
E	No. 2	*C. scopulosa*	0	many	absent	some	present	Pseudococcids	present
F	No. 1	*C. scopulosa*	0	many	absent	some	many	Pseudococcids	present
F	No. 2	*C. scopulosa*	0	many	absent	absent	many	Pseudococcids	present
G	No. 1	*C. scopulosa*	2 dealate queens; 2 queens with remnants of wings	many	many	many	many	Pseudococcids	present
G	No. 2	*C. scopulosa*	0	many	absent	absent	absent	Pseudococcids	present
H	No. 1	*C. scopulosa*	0	many	absent	absent	some	Pseudococcids	present
H	No. 2	*C. scopulosa*	0	many	absent	absent	many	Pseudococcids	present
I	No.1	*C. scopulosa*	1	many	absent	many	many	Pseudococcids	present
J	No. 1	*C. scopulosa*	0	many	absent	some	many	Pseudococcids	present
J	No. 2	*C. scopulosa*	0	many	absent	many	many	Pseudococcids	present

K	No. 1	*C. scopulosa*	2 (1 in basal part; 1 in apical part)	many living and dead workers	absent	many dead and living males	some	Pseudococcids; phorid fly (many immatures and a few adults); undetermined dipteran larva	absent
K	No. 2	*C. scopulosa*	0	many dead workers	absent	many dead males	absent	absent	absent
L	No. 1	*C. scopulosa*	0	many	absent	many	few	Pseudococcids	present
M	No. 1	no guest	0	absent	absent	absent	absent	absent	present
M	No. 2	*C. scopulosa*	0	many	absent	many	some	Pseudococcids	present
N	No. 1	*C. scopulosa*	0	some	absent	absent	present	Pseudococcids	absent
N	No. 2	*C. scopulosa*	0	many	many	absent	some	Pseudococcids	present
N	No. 3	*C. scopulosa*	0	some	1	absent	few	Pseudococcids	present
O	No. 1	*C. scopulosa*	0	many	absent	absent	some	Pseudococcids	present
O	No. 2	*C. scopulosa*	1	many	absent	absent	many	Pseudococcids	present

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