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Nesting substrata, colony success and productivity of the wasp *Mischocyttarus cassununga*

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ABSTRACT. Nesting substrata, colony success and productivity of the wasp *Mischocyttarus cassununga*. Colonies of the wasp *Mischocyttarus cassununga* (von Ihering, 1903) are easily found in urban areas. However, in spite of the massive presence of this species in cities, little is known about its nesting habits, colony success and productivity. The present study aimed at answering the following questions: What are the substrates used for nesting by *M. cassununga*? What is the main foundation strategy adopted by *M. cassununga* in urban areas: a solitary female or associative foundation? Is there a relationship between foundation strategies and colony success? Is the total number of cells per nest related to the number of adults produced? The study was conducted in Juiz de Fora, southeastern Brazil, from December 2006 to November 2007. Nesting in man-made substrata seems to be a common strategy in *M. cassununga* (90.9%), with preference for nest building with a horizontal comb facing north. The colonies were established mainly by groups of foundresses (67.6%), with a success of 84%. The number of brood cells produced per nest was 71.74 ± 45.25 (18–203), and it was positively correlated with the number of adults produced. Hence, we can say that the nests founded by *M. cassununga* are located mainly in man-made substrata and mostly founded by a group of females. The cell reuse behavior increases the number of adults produced, as it optimizes foraging. These characteristics together with its behavior and nesting habits promote the success of this species in thriving in urban environments.

KEYWORDS. Hymenoptera; Insecta; social wasp; urban environment; Vespidae.

Wasps of the genus *Mischocyttarus* Saussure, 1853 have an independent nest foundation strategy and a primitive social organization; their colonies rarely exceed one hundred individuals (Jeanne 1972, 1991; Prezoto *et al.* 2004). In tropical regions, foundation occurs at any time of the year by one solitary female (haplometrosis) or associatively by a group of females (pleometrosis) (Jeanne 1972; Poltronieri & Rodrigues 1976; Giannotti 1998; Penna *et al.* 2007b). Associative foundations may promote several advantages, such as higher productivity and survival rates, until workers emerge. In addition, associative foundations can assure a higher survival rate if the dominant female dies and may provide more effective defense against natural enemies (West Eberhard 1969; Jeanne 1975; Itô 1985).

The substrates selected by wasps for nesting provide the nests with crypticness. In the wild the foundation may occur under leaves, trunks, and in natural cavities (Jeanne 1991), whereas in urban areas, the colonies are frequently found in man-made structures, which shows a high synanthropism of the species (Fowler 1983; Lima *et al.* 2000; Prezoto *et al.* 2007; Alvarenga *et al.* 2010).

The Neotropical wasp *Mischocyttarus cassununga* (von Ihering, 1903) is easily found in southeastern Brazil. Its nest is composed of a single bare comb, attached to the substrate by an eccentric peduncle (Richards 1978). In spite of its massive presence in urban areas, little is known about its nesting habit, colony success, and productivity in this environment.

For these reasons, we intend to answer the following questions: What are the substrates used for nesting by *M. cassununga*? What is the main foundation strategy adopted by *M. cassununga* in urban areas: solitary female or associative foundation? Is there a relationship between foundation strategies and colony success? Is the total number of cells per nest related to the number of adults produced? Responses to these questions will promote a better understanding of the adaptation of *M. cassununga* in the occupation of urban areas.

MATERIAL AND METHODS

Study area and period. We conducted the study from December 2006 to November 2007 at the campus of the Federal University of Juiz de Fora, a site composed of green areas with recovered vegetation and buildings. This anthropic area is located at the municipality of Juiz de Fora, state of Minas Gerais, southeastern Brazil (21º46'S 43º21'W; average altitude of 678m).

Nesting substrata. To collect information about the foundation pattern of colonies of *M. cassununga* colonies, we made weekly visits to the colonies, preferably in the late afternoon (5 pm), when the individuals were finishing their foraging activities, allowing a more precise counting of the number of foundresses present in the colony. We checked the green areas and the building during the visits and recorded the following parameters: substratum type used for the colony foundation (n = 165), that was classified in two categories: man-made substrata and vegetation; position of the comb, height of the colony from the ground (n = 165); and direction of the comb: vertical or horizontal (n = 46), measured with a compass.

Colony success. We considered a successful colony the one that reached the post-emergence phase (according to Jeanne 1972), with the emergence of at least one adult. We monitored colonies from the foundation phase to the first adult's emergence and/or abandonment of the nest. We considered an unsuccessful colony the one that, after three consecutive visits, lacked adults, larval immatures, egg postures and new cells. For the analyses, we recorded the total number of cells of the colony at the end of the pre-emergence phase (n = 74) and the number of females involved during the colony foundation phase (n = 74).

Nest productivity analysis. We sampled 19 inactive nests that have already completed their colonial cycle. The nests were dissected and the information schematized in maps in standardized worksheets. For each nest, we recorded the following parameters: total number of cells, total number of productive cells, total number of adults produced (by the counting of meconium layers deposited in the cells), number of adults produced per cell and the ratio of produced adults/cells. We also recorded information on width and height (from the base to the top of the cell) of 438 cells, by the counting of meconium layers and their height inside the cell, using a caliper (Oliveira *et al.* 2010).

Statistical analysis. We used the Spearman test to calculate correlations between (a) the number of foundresses and the number of cells in the colony at the end of the pre-emergence phase; (b) the total number of cells and the total number of adults produced by the colonies; (c) the height of cells and the number of meconium layers. To test for differences between the categories used for nesting (man-made substrata and vegetation) and between the number of colonies constructed with vertical and horizontal comb we used the corrected Chi-squared test (Yates) ($p < 0.05$). To apply the tests we used the freeware software Bioestat 5.0.

RESULTS

Nesting substrata. The number of nests on man-made substrata (n = 150; 90.89%) was significantly larger ($\chi^2 = 110.455$; $p < 0.001$) than the vegetation substratum (n = 15; 9.09%). In man-made category we found colonies on several types of substrata: masonry (n = 75; 45.45%), metal (n = 56; 33.93%), roof tiles (n = 12; 7.27%), glass (n = 3; 1.81%), wood (n = 2; 1.21%), plastic (n = 1; 0.61%), and paper (n = 1; 0.61%). In the vegetation substratum the nests were found only under leaves.

The average height of the colonies from the ground was 2.55 ± 0.90 m (0.40–7.50). The number of nests with vertical peduncle and horizontal comb (n = 119) differed significantly ($\chi^2 = 31.418$; $p < 0.0001$) from the nests with horizontal peduncle and vertical comb (n = 46) (Fig. 1). Most colonies were north-oriented, between northwest and northeast, 271° to 90º (73.91%; n = 34).

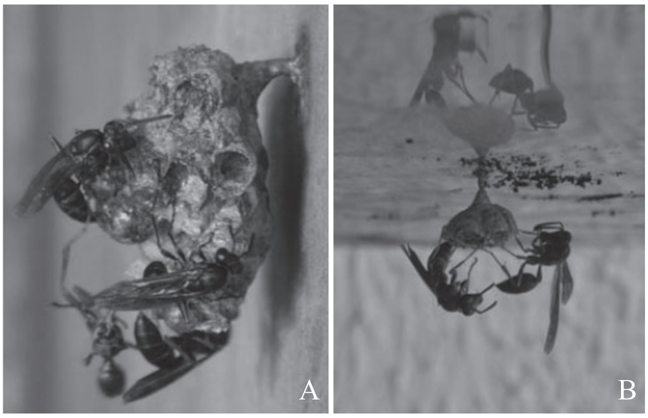

Fig. 1. Colonies of *Mischocyttarus cassununga* founded in man-made substrata: (A) horizontal peduncle and vertical comb and (B) vertical peduncle and horizontal comb.

Colony success. Most *M. cassununga* colonies were founded by a group of foundresses (n = 50; 67.57%) of which 84% (n = 42) obtained success. Colonies founded by a solitary female were less frequent (n = 24; 32.43%) and had a success of 37.5% (n = 9). Groups of two and three foundresses obtained a success of approximately 77%, whereas groups of four females had better chance of fully developing (91.67%), and five or more females achieved complete success (100%) (Table I). There was a positive correlation between the number of females involved in the foundation and the total number of cells produced at the end of the pre-emergence phase (r = 0.9286; p = 0.0009).

Table I. Frequency of foundation of colonies of *Mischocyttarus cassununga* according to the number of foundress females, success of colonies, and number of brood cells at the end of the pre-emergence phase (average, standard deviation, and range) in 74 colonies founded.

Number of foundresses	N	Frequency (%)	Success of colonies (%)	Number of cells at the end of the pre-emergence phase (range)
1	24	32.43	37.50	10.78 ± 4.82 (5–18)
2	18	24.32	77.78	12.78 ± 3.94 (6–21)
3	13	17.57	76.92	17.60 ± 7.97 (10–35)
4	12	16.22	91.67	24.36 ± 7.34 (12–36)
5	2	2.71	100.00	34.0 ± 4.24 (31–37)
6	1	1.35	100.00	40.00 ± 0
7	3	4.05	100.00	33.67 ± 8.5 (25–42)
9	1	1.35	100.00	45.00 ± 0

Nest productivity. The average number of cells produced per nest by *M. cassununga* was 71.74 ± 45.25 (18–203); the percentage of unproductive cells was 47.86 ± 9.54 (32-61.1%) and the average number of adults produced per nest was 63.63 ± 58.43 (12–243). The average number of individuals produced per cell was 0.78; we recorded a single cell being used five times at most (Table II). There was a positive correlation ($r = 0.9354$; $p < 0.0001$) between the total number of cells and the total number of adults produced in the colonies.

The unproductive cells of *M. cassununga* were concentrated in the periphery of the comb, whereas the cells that were used more times were located in the central region, the oldest in the comb. There was a positive correlation between the height of the cells and the number of meconium layers ($r = 0.6527$; $p< 0.0001$). The average width of the cells did not vary much in relation to the number of times they were used (2–3 mm) (Table III).

DISCUSSION

Nesting substrata. Some species of *Mischocyttarus* use human constructions as nesting substrata, even when elements from the natural environment, such as plants, are available (Jeanne 1972; Hermann & Chao 1984; Raposo-Filho & Rodrigues 1984; Simões *et al.* 1985; Lima *et al.* 2000; Alvarenga *et al.* 2010; Torres *et al.* 2011). The vegetation present in the anthropic environment was used by a small number of colonies, which might be attributed to the fragility of the plants, mostly species used for gardening that did not offer appropriate support for the nest, and exposed the nest to the weather. Characteristically, the vegetation in these areas consists of shrubs, small (usually less than 1 m high) and with small and deciduous leaves.

The results demonstrated the synantropism of *M. cassununga* in relation to the constructions with human interference. This can be explained in part by the fact that in this type of environment the colonies had better protection from human interference, bad weather, and direct sunlight, which can result in a higher chance of success. Other authors (Simões *et al.* 1985; Lima *et al.* 2000; Torres *et al.* 2011) also observed a preference of species of the genus for nesting in human buildings, in particular in sites protected from direct sunlight and rain.

The average height observed for nests of *M. cassununga* can be explained by the fact that most nests were found in man-made substrates, which have mostly predefined height such as for windows, ceilings, and roof tiles, which increases the height of the nests and making them discrete in relation to human perception. This result agrees with the standard height for wasp nests with independent foundation (genera *Polistes* and *Mischocyttarus*) observed by Alvarenga *et al.* (2010) in urban gardens in the city of Juiz de Fora, Brazil. Also, according to Lima *et al.* (2000), nests built below two meters in height are mostly likely to be destroyed or abandoned.

Table II. Comparative data of the productivity of 19 nests of *Mischocyttarus cassununga* collected in an urban area of the municipality of Juiz de Fora, southeastern Brazil.

Colony number	Total number of cells	Number of utilizations					% of unproductive cells	Adults produced	Adults produced/cell
		1	2	3	4	5			
1	18	4	1	2	–	–	61.10	12	0.66
2	30	15	–	–	–	–	50.00	15	0.50
3	35	12	2	–	–	–	60.00	16	0.46
4	35	12	3	1	–	–	54.30	19	0.54
5	35	14	5	–	–	–	45.70	24	0.68
6	43	18	7	3	–	–	34.90	41	0.95
7	44	18	3	–	–	–	52.30	24	0.54
8	44	19	5	–	–	–	45.40	29	0.66
9	52	16	7	–	–	–	57.70	30	0.57
10	68	21	9	–	–	–	55.90	39	0.57
11	71	26	13	9	–	–	32.40	79	1.11
12	76	21	10	3	1	–	53.90	54	0.71
13	80	15	11	11	8	1	42.50	107	1.34
14	83	9	18	6	–	–	60.20	63	0.76
15	84	33	16	–	–	–	41.60	65	0.77
16	108	34	15	7	7	6	35.20	143	1.32
17	113	47	13	–	–	–	46.00	73	0.64
18	141	39	16	11	6	1	48.20	133	0.94
19	203	76	30	23	7	2	32.00	243	1.20
Average	71.74	–	–	–	–	–	47.86	63.63	0.78

Table III. Height and width (average, standard deviation, and range) of the cells in relation to the meconium layers that have been deposited in the bottom as the cells are used to produce adult individuals of *Mischocyttarus cassununga* (n = 438).

Number of meconium layers	Number of cells (n)	Height of the layers (mm)	Height of the cells (mm)	Width of the cells (mm)
1	270	0.97 ± 0.11 (0.5–1)	10.73 ± 1.80 (6–18)	2.69 ± 0.27 (2–3.5)
2	107	2.02 ± 0.19 (2–3)	12.90 ± 1.90 (10–19)	2.72 ± 0.25 (2.5–3)
3	39	3.22 ± 0.44 (2.5–4)	15.41 ± 2.12 (12–20)	2.90 ± 0.20 (2.5–3)
4	15	4.60 ± 0.63 (4–6)	16.60 ± 2.67 (12–20)	3.00 ± 0.00
5	7	5.71 ± 0.75 (5–7)	18.57 ± 1.51 (16–21)	3.00 ± 0.00

In this study, the construction pattern of colonies of *M. cassununga* recorded may be explained by the search for protection against bad weather. In studies carried out in Brazil, colonies of *Mischocyttarus drewseni* Saussure, 1857 were mainly oriented to the west probably because in the study site storms come from the east (Jeanne 1972). Nests of *M. cerberus styx* (Richards, 1940) were oriented to the east towards the foraging area (Giannotti 1999). Montagna *et al.* (2010) did not find a preference for a particular nest orientation in *Mischocyttarus consimillis* Zikán, 1949, and also observed that the colonies may be founded horizontally, vertically or inclined.

Colony success. The foundation of a colony by a group of females was the predominant nesting strategy observed and resulted in the highest success in adult production. This strategy can be interpreted as optimal, since ecological pressures, such as parasitism and usurpation, social pressures, and an increase in survival levels are associated (West Eberhard 1969; Itô 1985).

The high index of failure of colonies founded by solitary females may be explained by abandon or death of the female during the initial phase of colony establishment. Wasps can migrate or associate themselves with other foundresses, which characterizes abandonment. On the other hand, the death of the foundress can be associated with its totipotency, which demands high energy and results in high exposure to risks such as predation (Jeanne 1991).

Dispute for hierarchical dominance is cited by Prezoto *et al.* (2004) as an event that can frequently cause the migration of females from one colony to another, where their hierarchical position can be more rewarding. Ultimately, this situation may contribute to the failure of these colonies, due to the loss of workers.

Nest productivity. The average number of cells and adults produced in the present study overpassed those found in other studies on *M. cassununga* (Gobbi & Simões 1988; Penna *et al.* 2007b). For other species of the genus, such as *M. cerberus* (Giannotti 1998; Penna *et al.* 2007b), *M. drewseni* (Penna *et al.* 2007a), and *M. consimillis* (Montagna *et al.* 2010), productivity, unproductive cells, and number of times a single cell was used varied greatly. These differences may reflect intrinsic biological characteristics of each species, as well as adaptive responses to the environments where the studies were conducted, which hinders comparisons between the species.

Likewise other species of the genus (Penna *et al.* 2007a, b; Montagna *et al.* 2010), *M. cassununga* presents a high rate of cell reuse in populous colonies. This behavior seems to promote reduction in work, which reduces the need for foraging for material to build new cells. The central cells of the comb had a higher frequency of use due to the discoidal pattern in nest building, where the central cells are older and thus mostly likely to be reused.

In urban areas, we can say that the nests founded by *M. cassununga* are located mainly in man-made substrata; they are mostly founded by a group of females. The higher the number of foundresses, the higher the chance of colony success. Cell reuse behavior increases the number of adults produced, as it optimizes foraging and reduces the need for searching for construction material and, therefore, increases the time for foraging for food. These characteristics, together with its behavior and nesting habits, promote the success of *M. cassununga* in thriving in urban environments.

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