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COMPORTAMENTO DE NIDIFICAÇÃO EM *Polybia platycephala* RICHARDS, 1978: DINÂMICA DE TEMPERATURA E LUMINOSIDADE

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Dissertação apresentada ao Instituto de Ciências Biológicas, Programa de Pós Graduação em Comportamento e Biologia Animal da Universidade Federal de Juiz de Fora, como requisito para obtenção do grau de Mestre

Orientador: Professor Doutor Fábio Prezoto

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A Adlai, que pra mim é pai, amigo e professor.

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RESUMO

Os ninhos de insetos sociais funcionam como a interface entre as colônias e o ambiente, e estudar como os fatores ambientais se relacionam com o comportamento de nidificação é essencial para compreender o sucesso desses animais em colonizar e sobreviver na área urbana. Dessa forma, este trabalho teve como objetivo estudar a relação entre a orientação dos ninhos da vespa social *Polybia platycephala* em áreas urbanas e a incidência de luz ambiental sobre os mesmos, além de descrever sua dinâmica de temperatura em relação ao microambiente em que estão localizados. Para a orientação e a incidência de luz, 11 ninhos foram selecionados em 2016 na cidade de Juiz de Fora, MG, sendo 11 na estação chuvosa e 11 na seca (n= 22). A orientação dos ninhos foi constatada e a incidência de luz de cada ninho foi verificada ao longo do dia (06:00h – 18:00h). Adicionalmente, seis ninhos tiveram sua orientação experimentalmente invertida e a luminosidade foi acompanhada antes e depois da inversão de forma a verificar o efeito da orientação natural sobre a exposição dos ninhos à luz. Para a dinâmica de temperatura utilizaram-se os mesmos 22 ninhos, e a temperatura dos ninhos e do ambiente foram medidas paralelamente à luminosidade. Para verificar o efeito da atividade das vespas sobre a temperatura da colônia, um ninho abandonado e uma colônia ativa foram acompanhados por 24 horas. Os resultados permitiram-nos concluir que *P. platycephala* apresenta uma orientação de ninhos fortemente enviesada para leste, aumentando a exposição à luz ambiental no período da manhã; são, no entanto, capazes de modificar esse comportamento para adaptar-se ao seu microambiente para otimizar essa exposição. A temperatura dos ninhos é muito relacionada à ambiente, flutuando paralelamente a esta, o que indica uma grande dependência das colônias do mesmo para sua sobrevivência. De forma geral, constatou-se que *P. platycephala* possui uma íntima relação com o seu microambiente, o que pode ajudar a explicar seu sucesso em colonizar áreas urbanas, mas também a torna sensível a alterações ambientais e climáticas nas mesmas.

Palavras-chave: Fatores ambientais, Ninho, Polistinae, Termorregulação, Vespas sociais.

ABSTRACT

Nests of social insects function as the interface between colonies and the environment, and studying how environmental factors relate to the nesting behavior is essential in order to understand these organisms' success in settling and surviving in the urban area. On this sense, our work aimed to study the relation between the social wasp *Polybia platycephala* nest orientation and the incidence of environmental light, aside from describing its temperature dynamics regarding the microenvironment where it is set. In order to study nest orientation and light incidence, 22 nests were chosen in 2016 in the city of Juiz de Fora, MG, being 11 in the rainy season and 11 in the dry (n= 22). Nest orientation was verified and light incidence on each nest was assessed through the day (06:00h - 18:00h). Additionally, six nests had their orientation experimentally inverted and luminosity was assessed before and after the inversion in order to verify the effect of nest orientation on exposure to light. In order to study temperature dynamics, the same 22 nests were used, and the nest and ambient temperatures were assessed in parallel with the luminosity. In order to verify the effect of the wasp activity on colony temperatures, an abandoned nest and an active colony were observed for 24 hours. The results allowed us to conclude that *P. platycephala* shows nest orientation strongly biased towards east, increasing exposure to light during the morning; colonies are, however, able to perform modifications on this behavior in order to adapt themselves to their microenvironment and optimize this exposure. Nest temperatures are intensely related to the ambient, fluctuating in parallel with it, which indicates a great dependence of the colonies on the environment to assure their survival. Overall, we found that *P. platycephala* has an intimate relation with its microenvironment, which may help explain its success in settling urban areas, but also makes it sensible to environmental and climatic changes in them.

Key words: Environmental factors, Nest, Polistinae, Social wasps, Thermoregulation.

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1. INTRODUÇÃO GERAL

A habilidade para construir estruturas complexas para habitação não é exclusiva do ser humano, estando presente em diversos grupos de animais – um fenômeno que pode ser referido como comportamento de nidificação (West-Eberhard, 1969; Hansell, 1984). Nos insetos, esse comportamento é mais evidente no grupamento dos insetos sociais, capazes de produzir construções que abrigam desde dezenas até milhões de indivíduos adultos e imaturos (Jeanne, 1975; Carpenter & Marques, 2001).

Nesse âmbito, as vespas sociais não são exceção. O grupo das Polistinae, vespas sociais neotropicais, apresenta não apenas uma diversidade enorme de espécies, mas também em seus hábitos de nidificação, podendo usar uma ampla gama de materiais de construção em seus ninhos que, por sua vez, possuem estrutura física variada e podem estar ligados a diferentes tipos de substrato (Jeanne, 1975; West-Eberhard, 1969; Carpenter & Marques, 2001).

Mais que um abrigo, entretanto, os ninhos das vespas sociais representam o *locus* da vida social (Starr, 1991) e seus limites físicos são os limites da colônia como um todo. A estrutura e os arredores de um ninho estão intimamente relacionados com a sobrevivência da colônia, uma vez que podem ser capazes de isolar a população de vespas de seus predadores, parasitoides e de condições ambientais adversas (Wenzel, 1991).

O gênero *Polybia*, foco deste estudo e extremamente representativo da fauna brasileira, é um claro exemplo dessas funções evolutivas do ninho, que é protegido externamente por uma camada de envelope e possuindo um pequeno orifício de entrada, a única interface direta entre o ninho e o ambiente (Richards, 1978). Essa interface é de grande interesse de estudo, uma vez que fatores ambientais abióticos como temperatura e a luminosidade são essenciais na regulação do crescimento e desenvolvimento de imaturos, além de influenciarem o comportamento de forrageio das operárias, que, por sua vez, tem uma íntima relação com todos os demais aspectos da vida colonial (Richter, 2000; Jones & Oldroyd, 2007; Castro et al., 2011).

Apesar da clara importância da relação entre o ninho e o ambiente com a sobrevivência das colônias, a grande diversidade de vespas e as variações no comportamento de nidificação entre o grupo das Polistinae faz com que a maior parte das espécies seja pouca ou nada estudada. Buscando aprofundar os conhecimentos nessa área, este trabalho teve como objetivo estudar o comportamento de nidificação na espécie de vespa social *Polybia platycephala* Richards, 1978, focando em sua relação com o ambiente em dois pontos

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específicos: (1) a relação entre a orientação geográfica dos ninhos e a exposição dos mesmos à luz ao longo do dia e (2) as flutuações da temperatura dos ninhos em relação ao ambiente ao redor. Acreditamos que esta investigação permitirá conhecer melhor esses aspectos do comportamento de nidificação no grupo, assim como realizar inferências acerca da evolução, da distribuição e do sucesso do grupo nos ambientes que colonizou.

2. REVISÃO DA LITERATURA

2.1. Distribuição e taxonomia

O gênero *Polybia* (Lepeletier, 1836) está contido na ordem Hymenoptera, família Vespidae, subfamília Polistinae (vespas sociais neotropicais), na tribo Epiponini (espécies de fundação enxameante); é o maior gênero da tribo, contendo 11 subgêneros e 58 espécies em sua plena distribuição (Carpenter et al., 2000), que vai do norte argentino até o sul dos Estados Unidos (Richards, 1978; Carpenter & Marques, 2001). No Brasil, o gênero apresenta cerca de 44 espécies e é considerado o mais representativo da fauna de vespas sociais do país (Richards, 1978; Carpenter & Marques, 2001; Barbosa et al., 2016).

A espécie *P. platycephala* está incluída no subgênero *Myraptera* e possui, por sua vez, duas subespécies: *P. platycephala platycephala* Richards e *P. platycephala sylvestris* n.. Exemplares da espécie foram registrados no Peru, Suriname e em todas as regiões do Brasil com a exceção do Centro-Oeste (Barbosa et al., 2016), o que mostra sua significativa distribuição pelo território Sul-americano. Na região do Sudeste brasileiro, a espécie apresenta alto sucesso na colonização de ambientes urbanos, onde sua presença é típica e relativamente abundante em relação a outras espécies de vespas sociais (Alvarenga et al. 2010; Barbosa et al., 2016).

2.2 Comportamento de nidificação

Os ninhos de vespas sociais possuem, como função primária, o fornecimento de um sítio onde os imaturos de uma colônia possam ser protegidos da ameaça de predadores e parasitoides, além de crescerem e se desenvolverem a um ritmo ótimo (Wenzel, 1991). O crescimento e desenvolvimento dos imaturos, por sua vez, são fortemente influenciados por fatores ambientais (calor, luz, umidade); portanto, um dos aspectos mais importantes da funcionalidade dos ninhos é controlar a flutuação desses elementos, mantendo-os em uma faixa ótima para seus habitantes (Jones & Oldroyd, 2007). De fato, em regiões tropicais como o Brasil, defende-se que o desequilíbrio causado por fatores abióticos como tempestades tropicais seja um dos elementos que exerça maior pressão seletiva no comportamento de nidificação do grupo (Wenzel, 1991).

Ninhos do gênero *Polybia* são construídos, em sua maioria, com fibras vegetais longas misturadas com água e enzimas salivares das operárias, com algumas poucas exceções que utilizam barro na construção de seus ninhos (Richards, 1978). A arquitetura do ninho, denominada fragmocítara, é composta de uma série de favos dispostos de forma semi-paralela recobertos por um envelope externo (Jeanne, 1975).

A espécie *P. platycephala* apresenta um ninho típico do gênero, onde o primeiro favo é iniciado diretamente no substrato, enquanto os favos subsequentes são construídos sobre o envelope do favo que o precede (Richards, 1978). Ninhos de *P. platycephala* são geralmente construídos sobre substrato vegetal, preferencialmente na superfície abaxial de folhas rígidas de árvores perenes, em locais quentes e sombreados (Lima & Prezoto, 2003; Prezoto et al., 2005). Após a descrição da espécie e de seus hábitos por Richards (1978), um único estudo foi publicado contemplando o comportamento de nidificação da espécie por Rodríguez et al. (2012), que registrou a espécie nidificando junto à outras em folhas de bananeiras (*Musa* sp.).

2.2.1. Nidificação e luminosidade

Conforme já citado, o funcionamento de um ninho de vespas sociais como interface entre o ambiente e a população da colônia é de grande interesse para o estudo da ecologia comportamental do grupo, uma vez que, além de regular o crescimento e desenvolvimento de imaturos, também influencia o ritmo e atividade de forrageio dos adultos (Richter, 2000; Castro et al., 2011). Dentre os fatores ambientais que mais ligam o comportamento de nidificação e a atividade das operárias, chamamos atenção nesse estudo para a temperatura e a luminosidade.

A luminosidade é um fator ambiental relacionado à atividade de colônias de insetos sociais, relação essa intermediada pelo comportamento de nidificação (Jones & Oldroyd, 2007). Os insetos sociais diurnos requerem uma quantidade mínima de luz ambiental para iniciarem a atividade de forrageio durante as manhãs, e, de forma similar, cessam a atividade quando esse limite é atingido no fim do dia (Giannotti et al., 1995; Detoni et al. 2015).

Assim, em diversas espécies do grupo, os ninhos possuem características que favorecem a exposição à luz solar no início pela manhã, período mais frio do dia, acelerando a atividade de forrageio desde cedo; alguns estudos clássicos feitos com cupins (Grigg &

Underwood, 1977) e formigas (Hubbard & Cunningham, 1977) que constroem ninhos no solo mostram uma tendência dos tais ninhos em possuírem superfícies amplas expostas à direção leste, o que otimiza o recebimento de luminosidade.

Nas Polistinae, que constroem ninhos longe do solo, geralmente em meio à vegetação, as colônias parecem preferir estabelecer-se em locais abrigados, porém com boa iluminação e aquecimento, visando o mesmo efeito de potencialização do comportamento de forrageio (Jones & Oldroyd, 2007; Kudô & Zucchi, 2009). No entanto, estudos feitos no grupo contemplando a orientação de ninhos não verificaram uma tendência clara das vespas em orientarem seus ninhos na direção leste como ocorre para outros grupos; de fato, a orientação pode ser enviesada para a região sul em algumas espécies do Hemisfério Norte (Steiner, 1932; Morimoto, 1957; Yamane & Kawamichi, 1975; Lorenzi & Turillazi, 1986), ou ser enviesada para norte no Hemisfério Sul, como verificado para *Polybia paulista* (Kudô & Zucchi, 2009); pode ainda nem mesmo apresentar uma orientação preferida, ou seja, apresentando ninhos randomicamente orientados, como ocorre para várias espécies do gênero *Polistes* no Japão (Matsuura, 1971). O único registro feito até então constatando uma espécie de vespa social que prefere orientar seus ninhos para leste foi feito para *Mischocyttarus mexicanus* por Gunnels et al. (2008), que discutiu esse resultado no âmbito da termorregulação de ninhos.

Dessa forma, os estudos que contemplam tanto a orientação dos ninhos quanto sua relação à luminosidade ambiental são escassos ao considerarmos o tamanho do grupo das vespas sociais. Estudar esse aspecto comportamental é, portanto, essencial para compreender as estratégias evolutivas de termorregulação no grupo, e, ao compararmos novos dados aos existentes, acreditamos ser possível relacionar o sucesso de cada espécie em colonizar o seu ambiente com a sua estratégia de adaptação às condições abióticas.

2.2.2. Nidificação e temperatura

A temperatura de uma colônia é provavelmente a variável abiótica mais estudada dentre os grupos de insetos sociais. Sua importância se faz clara no processo de desenvolvimento de imaturos, de forma semelhante aos demais grupos de insetos (Yamane & Kawamichi, 1975; Spielwok & Schmolz, 2006; Weissel et al., 2006), onde baixas temperaturas tendem a retardar o crescimento, mas temperaturas altas demais podem levar à letalidade. Adicionalmente, a atividade de forrageio de diversos grupos de Polistinae possui uma clássica relação com a temperatura, sendo potencializada com aumentos desta (Castro et al., 2011). Deve, portanto, haver um controle dessa variável de forma que ela permaneça num limite ótimo para a população (Jones & Oldroyd, 2007).

Tradicionalmente, a termorregulação é o nome que se dá ao processo de controle da temperatura de um organismo, visando à manutenção da homeostase para a sua sobrevivência; nos insetos sociais, esse processo se expande para o controle da temperatura dos ninhos e da colônia como um todo, conforme revisado por Jones & Oldroyd (2007). Estes autores classificam as estratégias de termorregulação dos insetos sociais entre ativas (compreendendo mecanismos etológicos e fisiológicos) e passivas, as quais estão basicamente relacionadas ao comportamento de nidificação (orientação e estrutura dos ninhos, local de nidificação). O estudo dos ninhos de vespas sociais em tais estratégias passivas de termorregulação, portanto, é de interesse para compreender os mecanismos evolutivos que permitem a adaptação do grupo a diferentes tipos de ambientes.

Para o gênero *Polybia*, os poucos estudos realizados permitem o estabelecimento de dois tipos de estratégias evidentes de termorregulação. O primeiro é o denominado "efeito de insulação" (*insulation effect*), um fenômeno resultante da arquitetura dos ninhos do gênero que permite uma relativa isolação do interior do ninho, o que auxilia na manutenção da homeostase (Hozumi et al., 2008). O segundo tipo de estratégia presente no grupo é o comportamento de incubação, caracterizado pela termogênese fisiológica que ocorre em colônias grandes e populosas; esse efeito foi verificado para a espécie *Polybia scutellaris* por Hozumi et al. (2010). Apesar de essas estratégias não serem de forma alguma excludentes, as espécies para as quais não foi observada termogênese (e, por tanto, dependendo quase que exclusivamente das estratégias passivas de termorregulação) apresentam uma intensa dependência da temperatura ambiental, o que resulta numa grande flutuação de temperatura ao longo do dia, enquanto *P. scutellaris* conseguem manter seus ninhos dentro de uma faixa estreita de temperatura mesmo durante a noite, de forma similar ao que ocorre com gêneros de vespas sociais de regiões temperadas (Himmer, 1931; Ishay & Barenholz-Paniry, 1991.), mantendo-se, portanto, independentes do ambiente. No entanto, dado que apenas três das 58 espécies do gênero foram estudadas nesse aspecto (Hozumi et al. 2005; 2008; 2010), não é possível estabelecer uma tendência geral do comportamento de termorregulação para o gênero e nem prever como se dará a dinâmica de temperatura para as demais espécies.

A preocupação em compreender as estratégias de termorregulação desses organismos e, principalmente, o grau de dependência das colônias do ambiente aumenta com as crescentes preocupações com os efeitos que mudanças ambientais possam ter sobre as populações de organismos ao redor do globo (ex.: Ojima et al., 1991; Dale et al., 2001; Balínt et al., 2011).

Além da sensibilidade geral dos insetos em relação às variáveis ambientais (Parks, 2011), um estudo feito por Dejean et al. (2011) busca demonstrar os efeitos que grandes eventos climáticos possuem nas faunas de vespas sociais, chamando a atenção de pesquisadores para a relação entre aumentos na temperatura e a sobrevivência do grupo em seu hábitat; assim, existe uma necessidade em conhecer os efeitos da temperatura ambiental sobre diferentes espécies no grupo, possivelmente identificando as que possam servir como bioindicadoras dos efeitos de aumento de temperaturas em longo prazo.

3. THE EFFECT OF NEST ORIENTATION ON EXPOSURE TO LIGHT IN *Polybia platycephala* RICHARDS, 1978

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ABSTRACT

The social wasps stand out among other animal groups due to their ability to build complex nests. These structures house their colonies and are responsible for protecting their brood, but also function as an interface between the individuals and the surrounding microenvironment. Among the environmental factors related to the nesting behavior, incident light is one of the most important due to its role as regulators of the colony's activity. Our objective on this study was to describe how environmental light incides on *Polybia platycephala* nests through the day in different seasons, and how the geographical orientation of the nest affects this event. The study was carried out in 2016, in the city of Juiz de Fora, Minas Gerais state, Brazil. Eleven nests were studied in the rainy season and another 11 in the dry season. Nest orientation was assessed through the use of a magnetic compass and inciding light was assessed at the nest openings with a lux meter at different hours of the day. Six additional nests were used in a reorientation assay in order to verify the effect of the orientation on the incidence of light. As described in the literature, the nests were strongly oriented to the east (90^o) and received slightly more light during the morning period than the afternoon, which may enhance foraging activity at the beginning of the day. Although nests whose orientation were closest to 90^o did not receive more light, nests whose orientation were experimentally inverted had an abrupt decrease of light incision during the first sampled hours. These results suggest that, although wasps show a strong trend in orienting their nests to the east, they are capable of adapting this behavior to the surrounding microenvironment in order to optimize the light income, especially during the morning.

Key words: Epiponini; Nesting; Regulation; Paper wasps; Polistinae.

INTRODUCTION

Of the many groups of animals capable of constructing complex structures, the social wasps (Hymenoptera: Vespidae) stand out due to their nesting behavior. Their nests vary greatly among species both in shape and in composition, and studies on the group's nest architecture usually try to explore this variability, searching answers for how and why these changes took form within the family (Jeanne, 1975).

The main purpose of the nest of the social wasps is to provide their brood with a proper environment for growth and development (Starr, 1991). This complex function can be decomposed into smaller parts such as maintaining optimal temperature and humidity (Starr, 1991), protecting the brood from parasitoids and predators (Jeanne, 1975; Clouse, 2001) and keeping the population safe from harsh environmental conditions (Wilson, 1971; Kudô et al., 2001). Of these, predation is thought to be the most influencing force in the evolution of the nest behavior (Jeanne, 1975); however, further investigation has been showing that social wasps nests may influence on many different behaviors, such as foraging (Hozumi et al., 2005; Gunnels et al., 2008) and resource storage (Prezoto & Gobbi, 2003; Prezoto et al., 2005; Guimarães et al., 2008).

The site chosen by wasps for building their nests must also be taken into account when studying nesting behavior. Studies have hypothesized that the nesting site may provide a buffer between the environmental temperature and the nest's, affecting how easily the workers can adjust the internal nest temperature according to the brood's demand (Jones & Oldroyd, 2007). In fact, the nesting behavior of a species is intricately related to their microenvironment, since the nest itself acts as the interface between environmental factors and the colony (Jones & Oldroyd, 2007). This relation is a key part of the colonial life, due to the role of environmental factors such as light, humidity and temperatures in regulating the development of immature wasps and the foraging activity of workers (Richter, 2000; Castro et al. 2011).

Nests of the genus *Polybia* Lepeletier, 1836 are a rather common sight in urban gardens and parks in throughout the Brazilian territory (Jeanne, 1991); in fact, this genus is the second most recorded in diversity studies on social wasps in Brazil (Barbosa et al., 2016). The construction of their nests is initiated by a founding swarm (West-Eberhard, 1982) and the structure is often made from vegetal fiber (Moebius, 1856; Wenzel, 1991). Nests are built from an initial comb directly on the nesting substrate, which is then covered by an envelope; an additional comb is built on the envelope of the first one, then covered by its own envelope, and so on, as the colony expands itself (Jeanne, 1975). When in advanced colonial stages, nests usually display a series of semi-parallel combs growing vertically downwards, with the ones in the bottom being usually larger than the former ones (Jeanne, 1975; Richards, 1978).

Thinking of the importance nesting orientation on the interface with environmental factors, this study was focused on the species *Polybia platycephala* Richards, 1978. The main effort in studying the nesting behavior of *P. platycephala* were made by Rodríguez et al. (2012), who reported the species nesting on *Musa sp.*. Being a widespread and abundant species in Brazil (Richards, 1978; Prezoto et al. 2005; Rodríguez et al., 2012), studying those aspects of the group's biology will help understand its success in colonizing urban areas.

Our objective, therefore, was to assess the variations in the incidence of light on nests of *P. platycephala* through the day in different seasons, and to verify how the orientation of the nests may affect this relation.

MATERIAL AND METHODS

Area and period of study

This study was carried out in the year 2016 in the city of Juiz de Fora, Minas Gerais state, southeastern Brazil (21°45'51.01"S, 43°21'1.01"W, 715 m asl). The area is classified by Köppen (1970) as Cwa, showing two distinct seasons: the dry season, between May and September, and the rainy season, October and April (CPC, 2009; Alvares et al., 2014).

Subject of study

Colonies of *P. platycephala* were located in the city's urban gardens and selected for study according to its accessibility. Colonies were identified as in the post-emergence phase through advanced nest size and intense foraging activity. Eleven colonies were observed on each season in order to assess inciding light throughout daytime, totaling 22 colonies. Data referring to the rainy season was sampled in April 2016, while the data on the dry season, in August 2016.

Additionally, six colonies were found and selected for study at the campus of Universidade Federal de Juiz de Fora, Juiz de Fora city, Minas Gerais state, southeastern Brazil (21°4'20" S, 43°20'40" W; 800 m asl) in order to perform the reorientation assay. All nests found were built on vegetal substrata, under the leaves of *Yucca sp.* bushes (Image 1). The assay was carried out between 12/25/2016 and 12/30/2016.

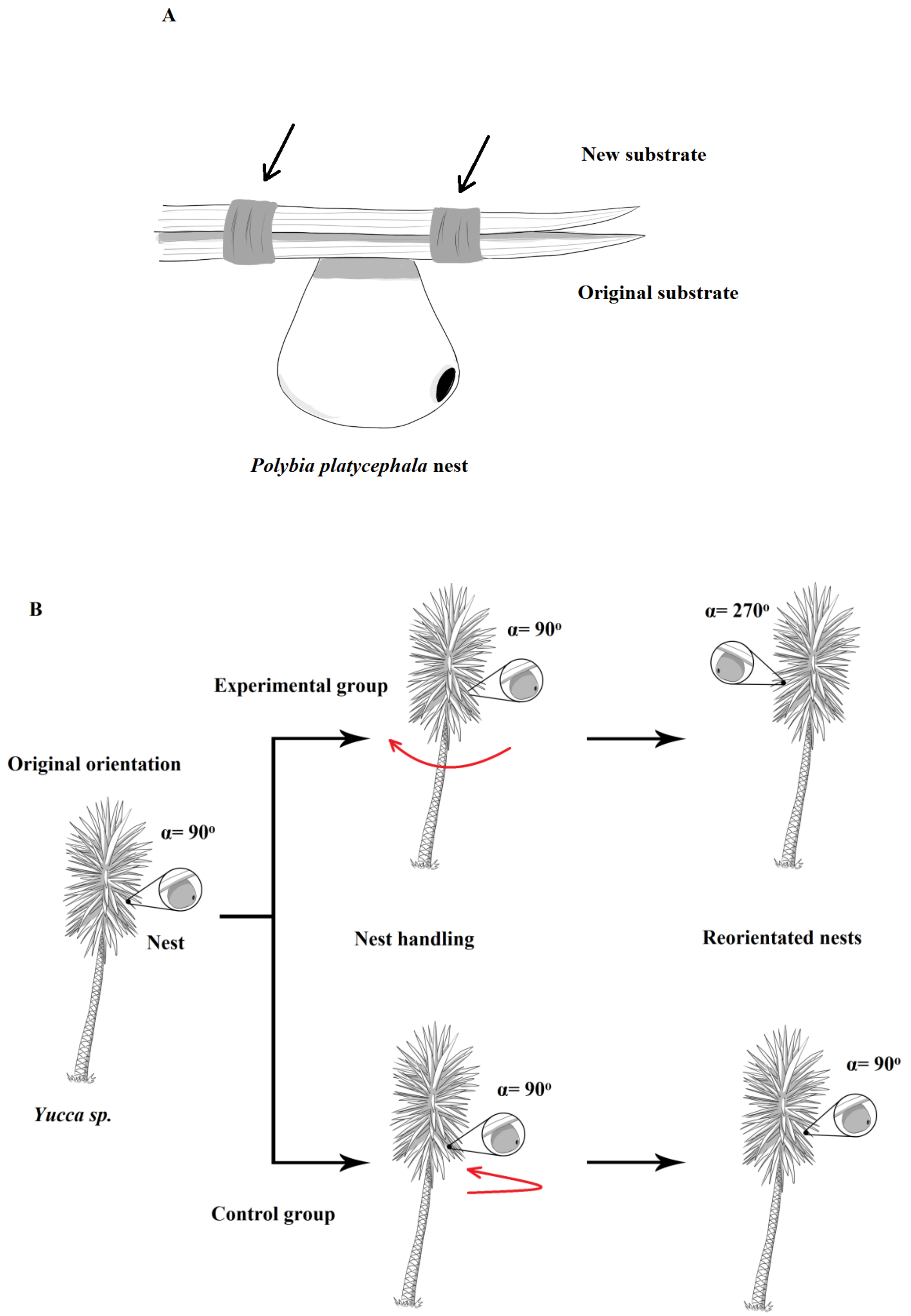

Image 1. Graphic representation of the *Polybia platycephala* nest reorientation assay method. A – Nest with original leaf substrate fixed to the new substrate. The black arrows indicate the points where the leaves were united through duct tape. B – Stages of the reorientation assay in the control group and the experimental group.

Nest orientation

The orientation of the opening of each of the 22 nests was measured a single time through a CSR DC-45-1© compass, which was held about 15 cm under the nests during the assessment; the magnetic North was used as reference for the 0^o mark (Kudô & Zucchi, 2009).

Inciding luminosity

The 22 chosen colonies were observed in order to assess the intensity of light inciding in their nest openings throughout daytime. Each colony was observed for one day, from 06:00 to 18:00 h; light intensity was measured through an Instruterm THAL-135 300© lux meter held directly in front of the nest openings, simulating its position and the light received by it. The intensities were recorded once in every three hours (at 06:00, 09:00, 12:00, 15:00 and 18:00 h).

Nest reorientation assay

In order to experimentally verify the effect of the orientation of nests on the luminosity at the nest openings, we performed a nest reorientation assay. The six nests found at the UFJF campus had their inciding light assessed (as in the “Inciding luminosity” method) for three consecutive days in order to observe a pattern; at the end of the third day, after sunset, three of these nests had their orientation inverted (in an 180^o turn), and the other three were treated as a control group. After the reorientation, the luminosity was assessed for the following three days, and the results pre and post-reorientation were compared.

The handling of *Polybia* nests is complicated due to their sensibility to disturbances and their intimate structural relation to the substrate; in order to reorientate the nests, we used a method developed by Prof. Rafael Carvalho and Prof. Sidnei Mateus (personal communication). The method consisted in removing the leaf on which the nest was built from the plant and fastening it to another leaf in the desired position with glue and duct tape (Image 1). As all six nests were built on *Yucca* bushes, which have their leaves positioned in an apical rosette through the stems, the experimental group was transferred to the leaves in the opposite direction immediately above the original leave, while the control group leaves where fixed to the first leave above the original position with the closest orientation.

Statistical analysis

The geographical orientation of the nest openings was analyzed through the Rayleigh directional statistics test. The Rayleigh V test was also used in order to confirm if the nest openings tended to be oriented towards East (expected value= 90^{o}).

The Mann-Whitney test was used to compare the mean intensity of incident light through the day for each nest in the rainy season versus the dry season, while the Friedman test for related samples was used to compare different times of day within the same season. The coefficient of variation (represented by the ratio of the standard deviation to the mean) was used to measure the dispersion of the frequency distribution of the luminosity.

A difficulty faced when comparing linear values (such as temperature or luminosity) with nest orientation is that, giving the latter's circular distribution, standard statistical tests are not effective to perform this task. Thus, in order to make such comparisons feasible, a simple equation was deducted that converts the angular values into linear values representing how much a nest's opening orientation is skewed towards an expected direction. The formula for this equation is:

$$AS = \left|1 - \frac{\alpha}{180°}\right|$$

In this equation, $\boldsymbol{\alpha}$ represents the smallest angular distance between the observed value and the expected value, represented by the formula:

$$\alpha = |\alpha_o - \alpha_e|$$

In which $\boldsymbol{\alpha_o}$ represented the observed angle for the opening orientation, while $\boldsymbol{\alpha_e}$ stands for the expected angle, having the magnetic North as a reference for the 0^{o}mark. This formulation process for this equation was supervised and approved by a qualified mathematician from the Department of Mathematics in Universidade Federal de Juiz de Fora.

The resulting **AS**, or angle skewing, is a linear value that ranges from 0 (when the observed angle is diametrically opposed to the expected angle) to 1 (when the observed angle is equal to the expected angle). Through this measure, we were able to test whether nests with openings that skewed more towards East (θ_e= 90^{o}) received more light and had increased temperature during different seasons or different times of the day; in order to compare this data, a Spearman's Correlation Coefficient test was performed ($p<0.05$).

RESULTS

Nest orientation

The Rayleigh test showed that the mean angle for nest openings orientation was 105.11^o in the rainy season ($Z= 2.52$; $p< 0.05$) and 89.73^o in the dry season ($Z= 3.70$; $p< 0.05$) (Image 2). For both seasons, the Rayleigh V test showed that nest openings were significantly biased towards 90^o, which represents the east (rainy season: $V=6.01$; $u=2.56$; $p<0.01$; dry season: $V= 6.38$; 2.72; $p< 0.01$).

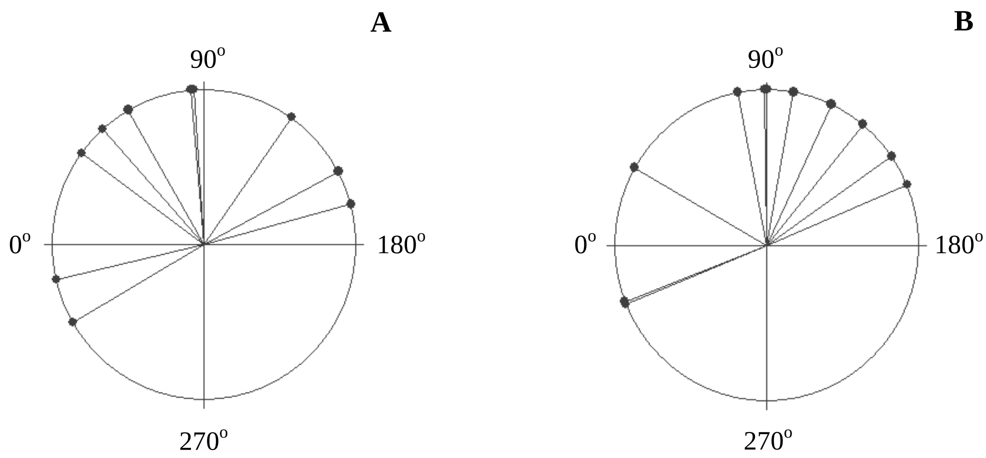

Image 2. Geographical orientation of *Polybia platycephala* nests in urban gardens of Juiz de Fora, MG, Brazil in the rainy season (A) and the dry season (B). The magnetic north was used as reference for the 0^o mark. Each nest is represented by a line that ranges from the center of the circle to its perimeter, ending in a black spot.

Incident luminosity

The intensity of the incident light on the nest openings was a mean 1,704.0± 1,728.5 lux (2-18,500 lux) in the rainy season and 2,398.1±805.6 lux (0-11,000 lux) in the dry season. Light intensity values for the rainy season varied greatly ($CV_r= 1.01$), while data sampled during the dry season was more evenly distributed ($CV_d= 0.33$). The Mann-Whitney test showed no significant difference in the intensity of light inciding on the nest openings between seasons ($U= 31.00$; $p= 0.052$).

Regarding the luminosity in different times of the day, for both seasons, the lowest scores were sampled during 18:00 h, while the highest scores were sampled during 09:00h (Image 3). Through the Friedman test for related samples, we were able to identify the same pattern for both seasons, as the data was organized into three overlapping groups: 1) lowest light intensity scores (06:00h and 18:00h); 2) intermediate light intensity scores (06:00h and 15:00h) and 3) highest light intensity scores (09:00h, 12:00h and 15:00h).

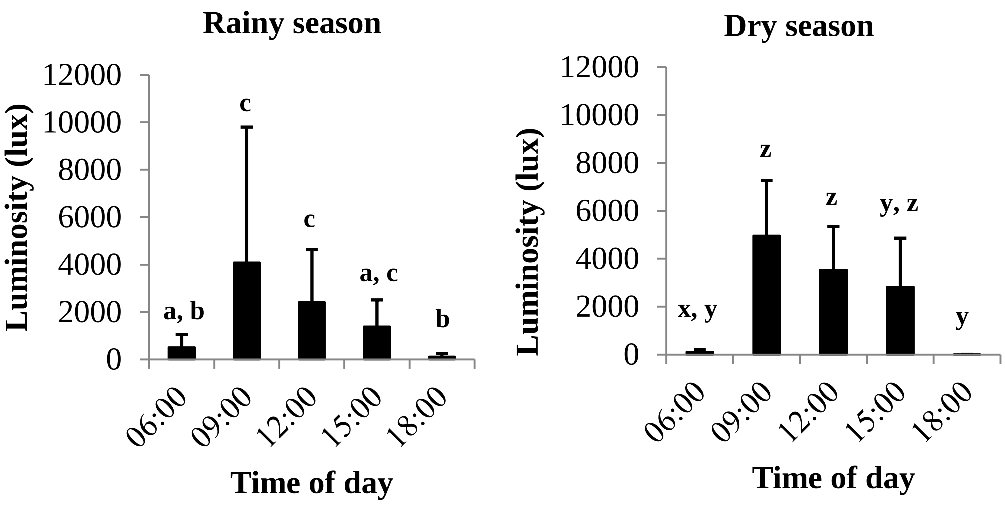

Image 3. Intensity of incident light on *Polybia platycephala* nest openings throughout daytime during the rainy and the dry season in urban gardens in Juiz de Fora, Minas Gerais, Brazil. The values indicated by bars represent the means, while the lines above them represent standard deviation. Bars showing the same letters within the same season have no significant difference between themselves (Friedman test, $\alpha = 0.05$).

Incident luminosity x Nest orientation

According to Spearman's correlation test, there was no significant correlation between nest openings skewing towards east and the amount of light inciding up on them at any time of the day in any season (rainy season: $r_s = 0.195$; $p = 0.56$; dry season: $r_s = -0.018$; $p = 0.95$).

Nest reorientation assay

Control nests had a mean 2375 lux before the treatment and 2251 lux after the treatment, while reorientated nests had a mean 4097 lux before the treatment and 1258 lux after it. As seen in Image 4, comparing the means before and after the treatment, control nests had their total inciding light intensity decrease by 5.3%, while in reorientated nests there was a 69.3% decrease. In the reorientated nests, the decrease of incident luminosity was clearly focused in 06:00h, 09:00h and 12:00h, while in 15:00h and 18:00h it increased in a low rate.

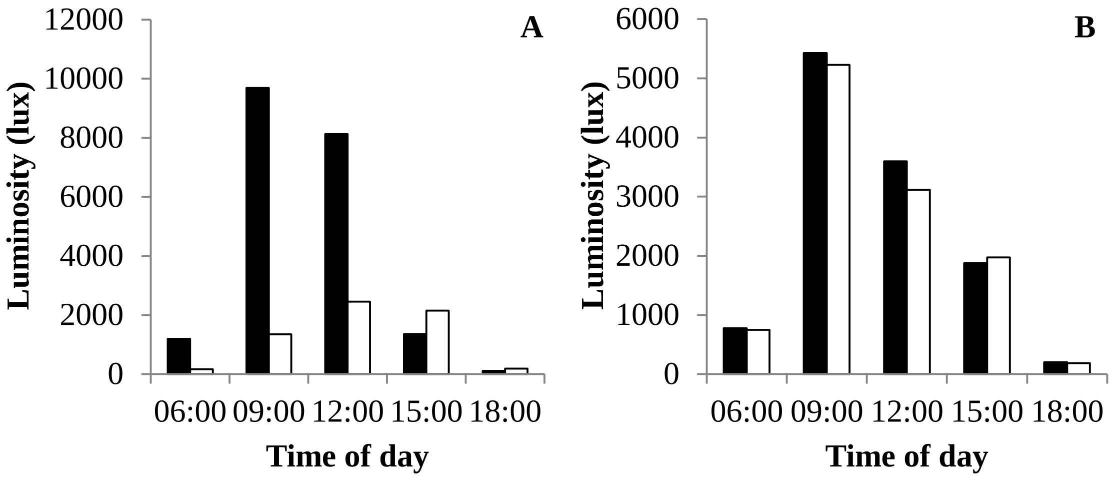

Image 4. Mean of the intensity of incident light on *Polybia platycephala* nests openings through the day before and after the inversion (180^o rotation) of their natural orientation (A) and in control groups (B) in December 2016, in the city of Juiz de Fora, MG, Brazil. Black bars correspond to the light measured on the original orientation, while white bars represent the light measured after the handling of the nests.

DISCUSSION

The results of this study showed that *P. platycephala* colonies have nonrandom orientation in the studied area, with nest openings being strongly biased towards the east. Some species of social insects such as ants are also known to use the eastern orientation in order to distribute their brood (Cole, 1994) or shape their nests (Grigg & Underwood, 1977; Hubbard & Cunningham, 1977), which can have significant effects on the colony's thermoregulation (Jacklyn, 1992). However, this trend is not observed for most studied social wasp species. It seems that *Vespa* species in Japan show random orientation (Matsuura, 1971), while the independent-founding *Polistes* prefer to face their nests towards the south in cold areas on the northern hemisphere (Steiner, 1932; Morimoto, 1957; Yamane & Kawamichi, 1975; Lorenzi & Turillazi, 1986). A most recent record shows that, for the closely related, swarm-founding Polistinae species *Polybia paulista* in southeastern Brazil, nests tend to be oriented towards north, supposedly to receive more solar radiation during the morning when compared to the southern orientation (Kudô & Zucchi, 2009). To the best of our knowledge, the only other study to show eastern orientation biasing in social wasps seems to be Gunnels et al. (2008), which observed the same phenomenon in the independent-founding *Mischocyttarus mexicanus*; the same explanation was suggested, in which females would show heightened activity during the morning due to increased exposure to light and higher temperatures (Stabentheiner et al. 2003; Spielwok & Schmolz, 2006; Weissel et al. 2006).

The assessment of the intensity of light inciding on nest openings during daytime showed that, although there wasn't an obvious difference between morning and afternoon (as it would be expected from the nest orientation), our results still support that nests receive more light during the morning, albeit in a more subtle way. This conclusion can be based on two facts: first, although the hours 09:00h, 12:00h and 15:00 did not differ significantly through the Friedman test, the mean value for light intensity was higher at 09:00h and decreased as time passed, being clearly higher than its counterpart in the afternoon, 15:00h. Second, the first time measured in the morning (06:00h) had intermediate values to the afternoon times 15:00h and 18:00h, since it was statistically similar to both of them, while they weren't similar between themselves. If light intensity was normally distributed, we would expect that counterparts (06:00h and 18:00h, 09:00h and 15:00h) were more alike, while our results support that these values are, despite subtly, higher during the morning.

Developing a method to organize nest orientation values, the angle skewing equation, was essential to correlate such data with light intensity and temperature during the day without artificially intervening with the nest orientations. On this sense, despite eastern orientation in social insect nest being related to the exposure to light and temperature in specific hours of the day (Jeanne & Morgan, 1992), this relation could not be supported by our results regarding *P. platycephala*. Why then would this species have such strong bias towards one specific orientation if not by sunlight exposure?

The nest reorientation assay was a key method to answer that question. When nests had their natural orientation inverted (rotated 180^{o}), their exposure to light during the day was clearly lower, especially during the morning period. A similar result was found with the reorientation of termite colonies by Jacklyn (1992). Such difference would not be expected if the natural nest orientation (on this population, strongly biased to east) had no effect on light exposure, as the Spearman test results suggest. However, by observing the nesting habits of the many hymenopteran groups, we were able to suggest a plausible solution to this dilemma.

The other studied species building nests influenced by the eastern orientation, such as the geometric termites (Grigg & Underwood, 1977; Jacklyn, 1992) and the ants (Hubbard & Cunningham, 1977), amongst many characteristics, differ from *P. platycephala* due to the surroundings of their nests. While these other hymenopterans are able to and usually build their nest in open areas, where the source of light during the day is almost entirely determined by the position of the sun, *P. playcephala* workers builds their nests under the leaves of trees and bushes, usually preferring unobvious and hidden locations. Light, in such places, although being originated from solar radiation, may be diffused and reflected by the environment much more easily than for ants and termites, and may incide from an orientation that does not directly correspond to the position of the sun. Additionally, *P. platycephala* was studied in an urban environment, where not only the vegetation and natural formations influence on the availability of light, but also the presence of human constructions must be taken into account (Alvarenga et al. 2010).

Therefore, according to our results, it seems clear to presume that, although nests prefer to be orientated to east in order to benefit from solar radiation (especially during the morning), *P. platycephala* colonies are able to adapt this behavior according to microenvironmental variations, choosing to build their nests facing the direction where light is most available. This strategy may be essential for these wasps in order to optimize the luminosity income on their nests even when these are built in environments where the spatial pattern is much different from their usual nesting sites, which enhances the species foraging activity and may be one of the factors that explain their success in settling urban environments.

4. TEMPERATURE DYMANICS IN NESTS OF *Polybia platycephala* RICHARDS, 1978

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ABSTRACT

Climate changes and the increase of temperature means can disturb the structure of animal populations and communities, and this process must be understood in order to avoid biodiversity losses. Social wasps, as most social insects, are sensible to these changes and must not only regulate their own internal temperatures, but also their nests' as a whole in order to avoid overheating in neotropical climates. The neotropical *Polybia* genus may or may not present strong thermoregulatory mechanisms, but few species have been studied on this sense. Our objective was to assess the behavior of the nest temperature variable when compared to the environment for the species *Polybia platycephala* Richards, 1978. The study was carried out in 2016, in the city of Juiz de Fora, Minas Gerais state, Brazil. Internal nest temperatures were measured through a sensor thermometer in one abandoned nest and one active colony and then compared with the surrounding environment for 24 consecutive hours. Additionally, the temperature of 11 nests was assessed through a laser thermometer and compared with the ambient temperature in the rainy season and in the dry season; the assessment was carried out once for each colony during a whole day, from 06:00h to 18:00h, every three hours. In both assessments, nest temperatures were closely related to the environment's. In the first assessment the active colony and the abandoned nest were similar through the day, while in the second nests almost always showed no significant difference to the environmental temperature (Wilcoxon test, $p<0.05$). Similarly to most studied *Polybia* species, *P. platycephala* nests seem to be strongly dependent on the surrounding environment in order to thermoregulate their colonies, which is a subtle process. These results show the species' vulnerability to environmental temperature changes and its potential as a possible indicator species for climate changes in urban areas.

Key words: Epiponini; Nesting; Paper wasps; Polistinae; Thermoregulation.

INTRODUCTION

Climatic changes and the increasing of Earth's mean temperatures have been a major discussion topic between scientists in many different fields for at least the last three decades (Ojima et al., 1991; Dale et al., 2001; Balínt et al., 2011). Amongst biodiversity researchers there is a great concern on how these temperature changes may affect the structure of biological populations and communities in short and long terms, with the endangerment and extinction of species being an ultimate consequence (Dale et al., 2001). On this sense, the insects stand out for their sensibility to climatic factors even in microscales (Parks, 2011), and many species among them may be studied as indicators for the impacts of temperature changes (Dejean et al., 2011).

Of the many insect groups, we highlight the social insects (ants, bees, termites and wasps) since their colonies function in many ways as superorganisms (Hölldobler & Wilson, 2008) and, as such, they must be able to maintain an internal homeostasis in the same way as an individual organism does (Jones & Oldroyd, 2006). As a result, these insects have developed behavioral and physiological thermoregulation strategies in order to control the temperature of their colonies. These strategies can be divided into active (behaviors performed by colony members) or passive, which are usually related to the nesting behavior and are a matter of great interest for the social wasps group (Jones & Oldroyd, 2006). In fact, the internal temperature of colonies seems to be a selective force in the evolution of nest architecture especially in the tropics, where many species live close to their lethal overheating limit due to high annual temperature means (Jeanne, 1975; Hozumi et al., 2008).

Among the social wasps found in Brazil, the swarm-founding *Polybia* genus is one the biggest, holding many different species and being the second most abundant in diversity studies (Richards, 1978; Barbosa et al., 2016). Their vegetal fiber enveloped nests are credited to provide the colonies with an insulation effect that helps maintaining the internal temperature at a constant (Hozumi et al. 2008). However, despite the variations on nest structure being well known within the genus (Jeanne, 1975), there are not many studies that actually investigate the role of nests in the regulation of the colony temperature. Of these, there seems to be two different trends regarding how the internal nest temperature fluctuates over time: while some species such as *Polybia paulista* (Ihering, 1896) and *Polybia occidentalis* (Olivier, 1791) depend almost solely on the ambient temperature to determine the temperature of their colonies (Hozumi et al., 2005), the species *Polybia scutellaris* (White, 1841) has been shown to have strong thermoregulatory strategies and to keep their nests under small temperature fluctuation (Hozumi et al., 2010). However, the genus *Polybia* comprises over 56 species (Richards, 1978), and these few studies can't establish which would be its main evolutionary thermoregulatory trend. In order to do so, other species on this genus must be investigated.

Polybia platycephala Richards, 1978 stands out within the *Polybia* genus for its great abundance in urban areas (Lima et al. 2000; Alvarenga et al. 2010). Despite its presence in urban gardens and parks, where it builds its nests on trees and bushes (preferably under large, rigid and broad leaves), the few existing studies on their nesting behavior are mainly descriptive, lacking investigation on the nest's auxiliary functions such as thermoregulation (Richards, 1978; Rodríguez et al. 2012). By choosing *P. platycephala* as a study subject, we are able not only to add knowledge to the thermal dynamics of the *Polybia* species, but also, due to its abundance in urban areas, it may present potential to be used as an indicator species for temperature changes in the urban environment.

Therefore, our aim in this study was to describe how the temperature behaves within the wasp nest, especially when compared to the environment, and try to understand the effect that the biological activity of the wasps has on nest thermoregulation.

MATERIAL AND METHODS

Area and period of study

This study was carried out in the year 2016 in the city of Juiz de Fora, Minas Gerais state, southeastern Brazil (21°45'51.01"S, 43°21'1.01"W, 715 m asl). The area is classified by Köppen (1970) as Cwa, showing two distinct seasons: the dry season, between May and September, and the rainy season, October and April (CPC, 2009; Alvares et al., 2014).

Subject of study

Colonies of *P. platycephala* in the post-emergence phase were located in the city's urban gardens and selected for study according to its accessibility. Eleven colonies were observed on each season in order to assess temperature throughout daytime, totaling 22 colonies. Data referring to the rainy season was sampled in April 2016, while the data on the dry season, in August 2016.

Additionally, a single active and another single abandoned colony were found and selected for study at the campus of Universidade Federal de Juiz de Fora, Juiz de Fora city, Minas Gerais state, southeastern Brazil (21°4'20" S, 43°20'40" W; 800 m asl) in order to compare nest temperature; data sampling was carried out between 09/27/2016 and 09/28/2016.

Abandoned Nest x Active Colony Temperatures

The method suggested by Hozumi et al. (2010) was modified in this study in order to assess the internal temperature of *P. platycephala* nests. Two nests of approximated sizes were selected for study, of which one was active and the other abandoned. Both nests were built on vegetal substrata and were situated about 5 meters apart, which conveniently minimizes the effects of microclimate variations. A sensor from a Minipa MT-240© digital thermo hygrometer was installed on each nest at 21:00 h in 09/27/2016, giving the active colony 12 hours to acclimatize to the sensor's presence. The observation began in 09/28/2016 at 09:00 h, from which the nest's internal temperature and the environmental temperature were recorded for each hour in the thermo hygrometer until 09:00 h on 09/29/2016, making up 24 hours of sampling.

Nest temperature x Ambient temperature

The 22 chosen colonies were observed in order to assess their temperature variation throughout daytime. Each colony was observed for one day, from 06:00 to 18:00 h; temperature was measured by aiming a laser digital thermometer (Raytek Mini Temp MT4©) at the opening of the nest envelope at a 1.5 m distance, while the environmental temperature was measured through an Instruterm THAL-135 300© thermometer located 1.5 m from the nest and on the same substrate. The temperatures were recorded once in every three hours (at 06:00, 09:00, 12:00, 15:00 and 18:00 h).

Statistical analysis

The means of environmental temperatures of the different days were stacked for each season and a Chi-Square adherence test was applied in order to verify whether these days differed significantly between themselves and therefore had any uneven effects on the nests.

For each season, the means of each nest temperature was compared with the ambient temperature at every time interval measured (06:00h, 09:00h, 12:00h, 15:00h and 18:00h) through the non-parametric Wilcoxon test for related samples.

RESULTS

Abandoned nest x Active colony temperatures

The abandoned nest showed a mean internal temperature of 16.82±1.12 °C (14.9-18.9 °C) while the active colony had 17.81±2.01 °C (14.7-21.2 °C). Ambient temperatures were a mean 17.35±1.73 °C (14.3-20.6 °C).

The comparison between the abandoned nest and the active colony temperatures in relation to the ambient temperature is shown in Image 5. In both cases, nest temperatures followed the ambient temperature, which can be seen by the distribution of temperature values along the Tn=Ta axis; however, there seemed to be a slight difference, since the active colony temperature was distributed mainly above the axis, while the abandoned nest temperature was below it.

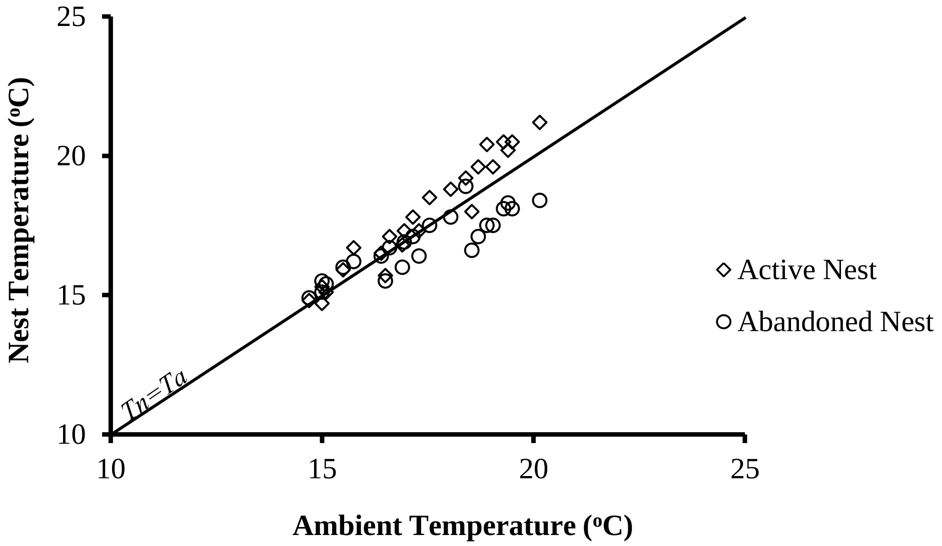

Image 5. Temperatures of an active nest and an abandoned nest of *Polybia platycephala* compared with ambient temperature for 24 consecutive hours between 09/28/2016 and 09/29/2016 in the campus of UFJF, Juiz de Fora, MG, Brazil.

Nest temperature x Ambient temperature

Through the Chi-Square adherence test, daily ambient temperature means didn't show any significant difference amongst themselves neither in the rainy season nor in the dry season ($p > 0.05$). Thus, we were able to rule out the effect that different days could have on our samples.

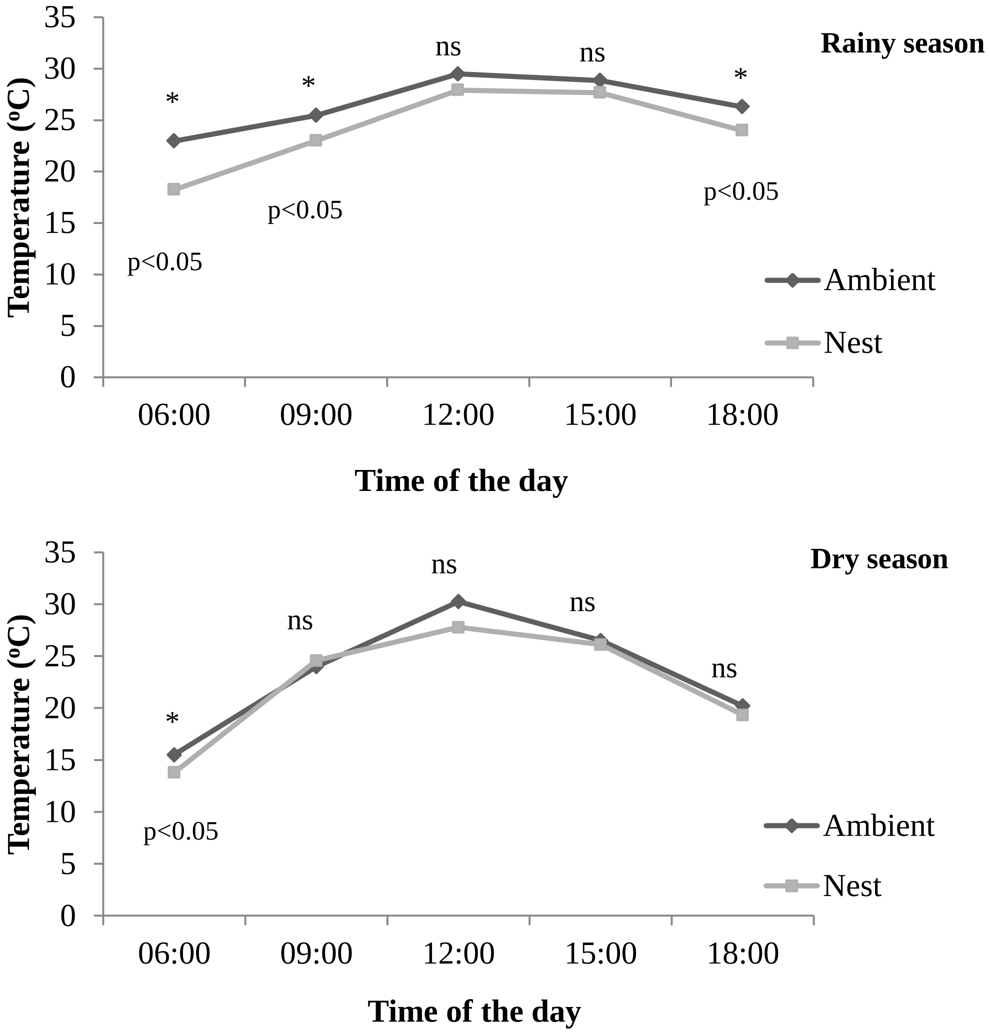

Image 6. Temperature of *Polybia platycephala* nest openings and the ambient throughout daytime (06:00h to 18:00h) during the rainy season and the dry season in urban gardens in the year 2016 in Juiz de Fora, Minas Gerais, Brazil. Hours marked with an asterisk (*) showed significant difference between ambient temperature and nest temperature (Wilcoxon test, $p < 0.05$), while hours marked with "ns" (non-significant) showed no such difference.

The variation of the nest temperature through the day is compared with ambient temperature in Image 6. As expected, ambient temperature means were lower during early morning and late afternoon, while the highest values were focused around 12:00 h; nest temperatures followed the same pattern, with both curves being similar in both seasons. Ambient temperatures were a mean 26.52± 3.05 ^{o}C (20.7- 35.5 ^{o}C) in the rainy season and 23.19± 5.25 ^{o}C (10.7 – 31.2 ^{o}C) in the dry season, while nest temperatures were a mean 24.03± 4.22 ^{o}C (15- 33 ^{o}C) in the rainy season and 22.12± 6.4 ^{o}C (11- 39 ^{o}C) in the dry season.

The Wilcoxon test showed that nest temperatures were significantly lower than ambient temperatures in 06:00 h for both seasons (rainy season: $Z = 2.93$; $p < 0.05$; dry season: $Z = 2.93$; $p < 0.05$), and in 09:00 h ($Z = 2.49$; $p < 0.05$) and 18:00 h ($Z = 2.93$; $p < 0.05$) only during the rainy season; for the remaining hours, nest temperatures did not differ significantly from the ambient's ($p > 0.05$). Generally, there seems to be a trend for the temperatures to become more alike in the hottest hours of the day (especially from 12:00 h to 15:00 h).

DISCUSSION

Comparing the internal temperature of an abandoned nest and an active colony is a simple way to highlight any differences in the nests' thermal dynamics caused by the biological activity of the wasps, be it through the physiologic generation of heat (thermogenesis) or by the execution of active thermoregulatory behaviors (wing fanning or water deposition). For *P. platycephala*, temperatures in both nests were similar to the surrounding environment's through the whole day, although the active colony seemed to have slightly higher temperatures than the abandoned nest, which could be caused by the presence of metabolic activity on the former.

Contrary to the described for *Polybia scutellaris* (Hozumi et al., 2010), in which metabolic heat generating seems to be a key part of colony thermoregulation, no evidence was found in this study supporting the existence of incubation behavior for *P. platycephala*. In fact, by comparing our data with the shown for *P. scutellaris*, two distinct models of temperature distribution can be seen, as represented in Image 7. For *P. scutellaris*, there is a clear difference between active colonies and abandoned nests; the former are kept within a specific temperature interval, even when the ambient temperature is much lower, while the temperature in abandoned nests seems to fluctuate according to the surrounding environment's. For *P. platycephala*, in this study, temperatures in both active colonies and abandoned nests behave similarly to the ambient temperatures; this suggests that, contrary to what happens in *P. scutellaris*, biological activity has no significant effect on the temperature of *P. platycehala* nests.

Comparing the curves of temperature throughout the day showed that the nest temperature has a greater difference during the colder hours, especially during the morning (06:00 h) and, as the ambient temperature increases, nest temperature gets higher and the difference decreases, getting to a minimum in the hottest hours of day (09:00h-15:00 h). A similar relation between nest and ambient temperature has been found in southeastern Brazil for the closely related *Polybia paulista* and *Polybia occidentalis* species (Hozumi et al., 2005) and, as discussed by the authors, the seemly absence of powerful thermoregulatory behaviors may a limiting factor in the species distribution, an argument that is supported by the absence of abundant *Polybia* species in high latitudes or altitudes (Richards, 1978; Carpenter & Marques, 2001).

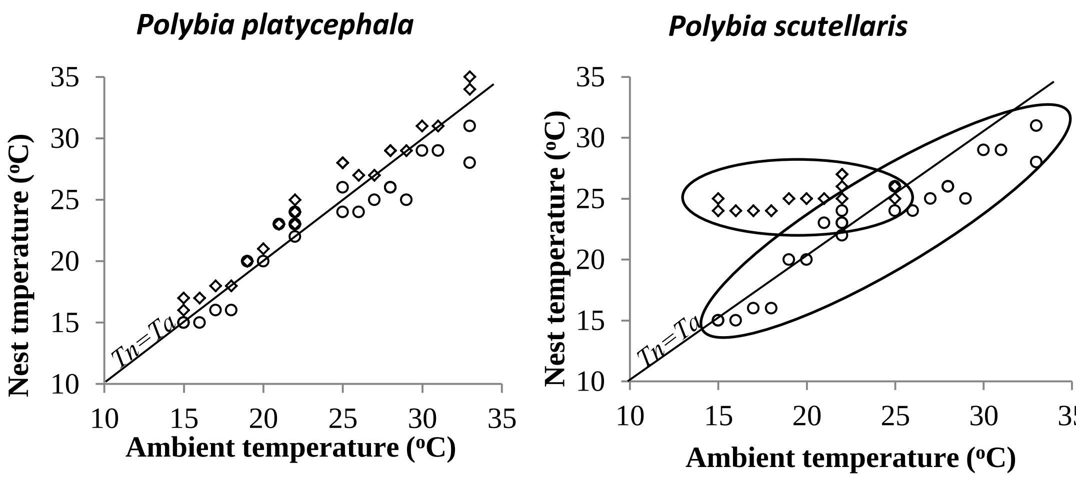

Image 7. Simplified representations of the temperature patterns of abandoned nests and active nests in *Polybia platycephala* and *Polybia scutellaris* compared to the ambient temperature through the day in southeastern Brazil. The lozenge marks represent the active nests, while the round marks represent the abandoned nests. The diagonal line represents the axis where nest temperature is equal to the ambient temperature (Tn=Ta). The model referring to *P. platycephala* was based on the results of the present study, while the one referring to *P. scutellaris* was based on the publication of Hozumi et al. (2010).

Having in mind the results from both applied methods, it is clear that, while some species of social wasps are capable to maintain the temperature of their nests under very small variation (Himmer, 1931; Ishay & Barenholz-Paniry, 1991; Hozumi et al., 2010), *P. platycephala* lacks this kind of refinement in nest thermoregulation. The species most highlighted trait, in this study, was the intimate relation between ambient temperature and the nests', a trend that seems to get stronger as the environment temperature increases. This behavior could be related to the species success in settling altered environments such as urban areas, which might present temperature fluctuations that are favorable to their survival; on this sense, however, the progressive warming of the temperature means in urban areas can pose a serious threat to the survival of this species – and possibly many others in the *Polybia* genus, such as *P. occidentalis* and *P. paulista* – since most social wasp species already live closely to their overheating temperature limit (Hozumi et al. 2008).

Long-term monitoring of the urban populations of *P. platycephala*, especially in zones where they are abundant (such as Southeastern Brazil), can be a useful tool when associated to data on the temperature of these areas in order to generate knowledge on the effects that environmental changes and the increase of temperature means may have on the social wasp fauna.

5. CONSIDERAÇÕES FINAIS

Este estudo trouxe resultados inéditos para o conhecimento sobre as interações entre ninho e ambiente na vespa social *P. platycephala* em ambiente urbano, além de contribuir para o conhecimento geral de aspectos da termorregulação e nidificação no gênero *Polybia*, grupo pouco estudado a despeito de sua abundância em tal meio. A espécie apresenta um comportamento comum dentre os insetos sociais de orientar seus ninhos para a direção leste sendo, entretanto, capaz de adaptar essa estratégia de acordo com microambiente ninho para melhorar a incidência de luz sobre o mesmo, uma estratégia ainda praticamente desconhecida para as vespas sociais. A temperatura dos ninhos de *P. platycephala*, por sua vez, mostrou uma íntima relação com a temperatura do ambiente e a espécie aparenta possuir pouco controle sobre a flutuação dessa temperatura, fenômeno compartilhado com a maioria das espécies do gênero *Polybia* já estudadas. Assim, de forma geral, fica clara a força da relação entre a espécie e o microambiente que envolve suas colônias, relação da qual o ninho faz parte ativamente. É possível, portanto, que o ambiente urbano apresente uma estrutura e uma dinâmica favoráveis para a espécie, o que explicaria seu evidente sucesso ao colonizá-lo e que pode também se provar verdadeiro para outras espécies de vespas sociais abundantes no mesmo. Entretanto, essa intimidade também pode significar uma sensibilidade a mudanças ambientais que ocorram nesse ambiente, sendo, portanto de interesse que se dê continuidade ao estudo do comportamento e dos hábitos do grupo e sua relação com o ambiente.

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