First record of the interaction between the arthropod-pathogenic fungus *Gibellula* and a new species of harvestman *Auranus* (Stygnidae) narrowly endemic to the Brazilian rain forest

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Abstract

Harvestmen are one of the largest groups of arachnids with more than 6,500 species distributed in 1,500 genera and 50 families. However, the interactions between harvestmen and arthropod-pathogenic fungi have rarely been studied. Certain previous studies report that fungal attack represents one of the most important factors for the mortality of harvestmen, but the fungus has rarely been identified, and most of the important information about the fungus-host interactions remains unrecorded. In the present study, we have described the new species *Auranus quilombola* **sp. nov.** and reported its interactions with the arthropod-pathogenic fungus *Gibellula* sp. *Auranus quilombola* **sp. nov.** belongs to the family Stygnidae, and it is endemic to the humid mountain forests of Ceará state, Brazil in an area of endemism known as *Brejos Cearenses*. The species is related to five other species of *Auranus*, all of which have been recorded from the Amazon rainforest. A taxonomic description of this new species and its biogeographic implications have also been discussed in this paper.

Key words: *Akanthomyces*, *Brejos Cearenses*, Laniatores, biogeography

Introduction

Arthropod-pathogenic fungi form a phylogenetically diverse group that is capable of attacking insects and using them as hosts to complete a part of their life cycles (Vega *et al*. 2012). These fungi can be described as facultative or obligate parasites with high sporulation abilities and survival rates (Delgado & Murcia-Ordoñez 2011); they are particularly interesting as they can be considered as potential candidates for biological insect (Mullens *et al*. 1987; Vega *et al*. 2012). Many of these fungal parasites are able to manipulate the behavior of their hosts. One of the most well-known cases of behavioral manipulation in hosts in the association between the entomopathogenic fungus, *Ophiocordyceps unilateralis* complex and the Camponotini ants (Hughes *et al*. 2011; De Bekker *et al*. 2014). In this case, the fungus-infected ants invade their nests and climb into the foliage, where they attach themselves to the vegetation by locking their jaws on it to prevent themselves from falling down. After the death of the ant, fungal hyphae grow on the outer body surface, and new spores are dispersed from there, which can infect new individuals (Andersen *et al*. 2009; Pontoppidan *et al*. 2009; De Bekker *et al*. 2014).

Among the pathogenic fungi that infect arthropods, the two most well-known genera are *Gibellula* (Cavara 1894 and *Torrubiella* Boudier 1885 now synonymized with *Akanthomyces*, Kepler *et al*. 2017), consisting of 23 and 80 species, respectively (Kobayasi & Shimizu 1982; Kirk 2019). These fungi primarily attack spiders and scale insects, with *Gibellula* being exclusive to spiders (Johnson *et al*. 2009**)**. In the case of *Torrubiella*, the type species *Torrubiella aranicida* Bound, 1885, was first described from material collected from an unidentified spider (Johnson *et al*. 2009), but different species of this genus had been previously reported to infect other arthropods (Kobayasi & Shimizu 1982). For *Gibellula*, most species are restricted to hosts of a particular order or family, but hosts are often difficult to identify in terms of genus or species. Therefore, the degree of host-specificity of these fungi is poorly understood (Hywel-Jones 1993; Kobayasi & Shimizu 1982).

Harvestmen are one of the largest groups of arachnids with more than 6,500 species distributed in 1,500 genera and 50 families (Giribet & Sharma 2015). They are found in the tropics as well as the subarctic regions, thereby presenting a cosmopolitan distribution (Curtis & Machado 2007). Harvestmen represent an important group of predators of small arthropods or scavengers; they can generally be seen on the ground and on tree trunks. (Acosta & Machado 2007; Giribet & Sharma 2015). Nevertheless, reports on the interactions between harvestmen and arthropod-pathogenic fungi as well as information about the possible behavioral modifications caused by these pathogenic fungi in their hosts are relatively scarce (Cokendolpher 1993). Some studies have indicated that fungal attack represents one of the most important factors for the mortality of the harvestmen (Machado & Oliveira 1998; Machado & Raimundo 2001). However, the fungus is rarely identified and most of the important information about the fungus-host interactions remains unrecorded (Machado & Oliveira 1998; Machado & Raimundo 2001). To the best of our knowledge, there are only three published records describing the fungus-harvestmen interactions, where the fungus has been identified: (1) Barbosa *et al*. (2016) reported that the harvestman *Acanthogonyleptes* sp. (Gonyleptidae) was attacked by the fungus *Torrubiella* cf. *aranicida*); (2) Santamaria *et al*. (2017) reported that the harvestman *Dicranolasma scabrum* group (sensu Gruber 1998) (Dicranolasmatidae) was attacked by the fungus *Opilionomyces dicranolasmatis* (Santamaria, Enghoff, Gruber, & Reboleira, 2017), and 3) Cokendolpher (1993) reported that a harvestman of the family Gonyleptidae was attacked by the fungus *Torrubiella gonylepticida* Møller. However, in these studies, the biological aspects and the ecological implications af these interactions have not been reported in detail.

The family Stygnidae (Simon 1879) is one of the most diverse families of harvestmen, with 111 described species restricted to the Neotropics (WCO-Lite 2019; Kury *et al*. 2021). It possesses taxa that are distributed throughout the Amazon, Andean, Caribbean, and eastern Brazil (Atlantic rain forest, Cerrado savannah, and Caatinga semi-arid) regions (Colmenares *et al*. 2016). The family includes the genus *Auranus* (Mello-Leitão 1941), which comprises five described species; it is a group of tiny leaf-litter dweller harvestmen, distributed across the Brazilian states of Amazonas, Pará, and Roraima (Pinto-da-Rocha & Tourinho 2012; Colmenares *et al*. 2016). The only biological or ecological information that is known of this genus is about the type species *A. parvus* (Mello-Leitão 1941), which can be found in the trunks or in the canopy during periods of intense rain (Friebe & Adis, 1983 *apud* Pinto-da-Rocha 1997). The rest of the information is restricted to taxonomic data and description of new species (Pinto-da-Rocha 1997; Pinto-da-Rocha & Tourinho 2012; Colmenares *et al*. 2016).

In the present study, our objectives were to: (1) describe the interaction between the arthropod-pathogenic fungus *Gibellula* sp. and the harvestman *Auranus quilombola* **sp. nov.** (Laniatores, Stygnidae), (2) provide a taxonomic

description of *Auranus quilombola* **sp. nov.**, and (3) discuss the endemism and biogeographic implications of the new species.

Materials and methods

Study area
The study of fungus-harvestmen interactions was carried out in the municipality of Itapipoca (Quilombo Nazaré, 3°33.772′S, 39°33.031′W; altitude of 840 m), Ceará State, Brazil. The locality is situated in a *Brejo de Altitude* that includes enclaves of humid mountain forests among the scrublands of the Caatinga, a semi-arid ecosystem that covers the northeast region of Brazil.

Taxonomic treatment
The specimens were deposited in the collections of the Coleção de Aracnídeos da Universidade Federal da Paraíba (Col. UFPB), Museu Nacional da Universidade Federal do Rio de Janeiro (MNRJ), and Museu de Zoologia da Universidade de São Paulo (MZSP). The external morphology of the specimens was described according to the terminology used by Acosta *et al*. (2007) and Kury & Medrano (2016). Genital chaetotaxy and terminology were assigned as described by Kury & Villarreal (2015). The male genitalia of the specimens were mounted in glycerin and later examined. Photographs were taken under a microscope (Zeiss Primo Star) using a dedicated software (Zen blue edition). Measurements ff the external morphological characters were recorded with an automated stereomicroscope Leica M205C system, a DFC295 Leica camera, and the dedicated software Leica Application Suite version 4.0.0 (build 877) (Leica 2003–2011) at UFPB. Drawings were made using Inkscape version 0.94.2 software. All the measurements were recorded in mm.

Fungus-harvestmen interactions: Harvestmen sampling
On May 5 and 6, 2019, during a field expedition in the study area, we manually collected the harvestman *Auranus quilombola* **sp. nov.** Some of these collected specimens were parasitized by the fungus *Gibellula* sp. while others were not. We carried out the collections during the day between 10:00 and 14:00 hrs. We photographed the harvestmen in the field and subsequently placed them in plastic containers (8 × 10 × 10 cm) sealed with tulle fabric to identify the harvestmen and the parasitic fungus. All the harvestmen that were collected, both infected and uninfected, were found on the trunks of various tree species in the same transect. We also recorded the length and width of the harvestmen's dorsal shields to determine whether the probability of infection by the parasitic fungus was influenced by the body size of the harvestman.

Results

Taxonomic treatment

Family Stygnidae Simon, 1879

Auranus Mello-Leitão, 1941

Auranus Mello-Leitão 1941: 441; Pinto-da-Rocha 1995: 196; Pinto-da-Rocha 1997: 263; Kury 2003: 228; Pinto-da-Rocha & Tourinho 2012: 1, 10, 11, figs 12, 13, 24, 25; Kury & Villarreal 2015: 12, 29, 30, 32, 40; Colmenares *et al*. 2016: 117, 118, 119, 122, 124, 125, figs 120, 121, 123, 126, 127; DeSouza *et al*. 2017: 20, 21, fig, 3A; Villarreal *et al*. 2019: 986, 987.

Species included. *Auranus parvus* (Mello-Leitão 1941; type species), *Auranus hehu* (Pinto-da-Rocha & Tourinho 2012), *Auranus leonidas* (Colmenares *et al*. 2016), *Auranus tepui* (Pinto-da-Rocha & Tourinho 2012), *Auranus xerxes* (Colmenares *et al*. 2016), and *Auranus quilombola* **sp. nov.**

***Auranus quilombola* sp. nov. Araújo-da-Silva & DaSilva**

Auranus sp. DeSouza *et al.* 2017: 20, 21, Fig, 3A.

Type material: BRAZIL. *Ceará*: Guaramiranga, Parque das Trilhas, ~900 m.a.s.l., 06.iv.2011, Araujo-da-Silva, L.P. *et al. leg.* 1♂ *holotype* (UFPB-OP901); idem, 9♂ 8♀ 6 juv. *paratypes* (UFPB-OP299). *Other paratypes.* Guaramiranga, Parque das Trilhas, 01.vi.2018, Da Silva, M.B. *et al.* leg. 9♂ 8♀ 6 juv. (UFPB-OP893); Guaramiranga, Trilha da Cachoeira do Urubu, 05.iv.2011, Araujo-da-Silva, L.P. *et al.* leg., 9♂ 8♀1juv. (UFPB-OP302); Baturité, Reserva Particular Patrimônio Natural Sítio Palmeiras, 750 m.a.s.l., 03.iv.2011, Araujo-da-Silva, L.P. *et al.* leg.,10♂ 10♀ 4juv. (UFPB-OP022); idem, 6♂ 3♀ (MNRJ59055); Baturité, Fazenda do Dr. Antônio Carlos (CE-356), 04.iv.2011, Araujo-da-Silva, L.P. *et al.* leg., 11♂ 11♀ 3juv. (UFPB-OP268); idem, 6♂ 3♀ (MZSP76644); Pacoti, Hotel Chalé Nosso Sítio, ~760 m.a.s.l., 25.iv.2015, Da Silva, M.B. *et al.* leg., 3♂ 5♀ 2 juv. (UFPB-OP894) idem, 1♂ (UFPB-OP902); Pacoti, Forquilha (CE-253), ~900 m.a.s.l., 26.iv.2015, Da Silva, M.B. *et al.* leg., 1♂ 1♀ (UFPB-OP953); Itapipoca, Mata de São João, 03.vi.2018, De Souza, A.M. *et al.* leg., 6♂ 1♀ 1 juv. (UFPB-OP895); Itapipoca, Quilombo Nazaré, 840 m.a.s.l., Nóbrega, F.A.S. *et al.* leg.,1♂ 2♀ (UFPB-OP804); Pacatuba, Serra da Aratanha, trilha ao lado do Parque das Andreas, ~350 m.a.s.l., 15.ii.2013, Costa, A. *et al.* leg., 3♂ 6♀ (UFPB-OP119); Pacatuba, Serra da Aratanha, 07.iv.2011, Da Silva, M.B. *et al.* leg., 27♂ 13♀ 4 juv. (UFPB-OP896); Maranguape, Serra da Pirapora (Sítio Europa), ~450 m.a.s.l., 08.iv.2011, Araujo-da-Silva, L.P. *et al.* leg., 40♂ 19♀ 1 juv. (UFPB-OP897); Ubajara, Parque Nacional de Ubajara, Brejo de Altitude, ~700 m.a.s.l., 27.i.2014, Sampaio, C., Saraiva, N.E.V., Da Silva M.B. leg., 6♂ 10♀ (UFPB-OP172); Ubajara, Parque Nacional de Ubajara, Rio Gameleira, 840 m.a.s.l., 27.i.2014, Sampaio, C., Saraiva, N.E.V., Da Silva, M.B. leg., 2♂ 3♀ (UFPB-OP189); idem, 5♂ 5♀ (UFPB-OP162); Ubajara, Cachoeira Bica do Vitalino, 813 m.a.s.l., 25.x.2011, De Souza, A.M., Araújo, E.S., Vilarinho, N. leg., 16♂ 19♀ (UFPB-OP218); Ubajara, Cachoeira Bica do Vitalino, 813 m.a.s.l., 26.x.2011, De Souza, A.M. *et al.* leg., 8♂ 3♀ (UFPB-OP225); Ubajara, Bica do Vitalino, 25.x.2011, Vilarinho, N. *et al.* leg., 2♂ 1♀ (UFPB-OP226); Ubajara, Trilha do Portão Planalto, 838 m.a.s.l., 27.x.2011, Araujo, E. *et al.* leg., 1♂ (UFPB-OP227); Ubajara, Sítio do Alemão, 891 m.a.s.l., 23.x.2012, De Souza, A.M. *et al.* leg., 1♂ (UFPB-OP228); Ubajara, Gruta do Morcego Branco e Gruta de Ubajara, ~520 m.a.s.l., 22.x.2011, De Souza, A.M. *et al.* leg., 4♂ 7♀ (UFPB-OP231); Ubajara, Trilha da Samambaia, 900 m.a.s.l., 30.iv.2018, Silvino, A.C.S. *et al.* leg., 5♂ 1♀ (UFPB-OP694); Ubajara, Trilha da Samanbaia, 1.v.2018, Silvino, A.C.S. *et al.* leg., 4♂ 4♀ 1 juv. (UFPB-OP714).

Diagnosis: Similar to *A. hehu* by the presence of two ventral rows of tubercles in tibia IV. It can be distinguished from *A. hehu* and *A. parvus* due to the presence of one large, dorso-ectal, apical tubercle and one ventro-ectal, apical tubercle on its patella. It differs from *A. hehu*, *A. leonidas,* and *A. parvus* in having an undivided area II. It differs from *A. tepui* and *A. leonidas* in having a row of granules on the lateral margins of its dorsal scutum.

Etymology: "*quilombola*" is a Brazilian Portuguese name for a person who lives in a *quilombo*, a settlement inhabited by black slaves after they escaped from their exploitative landlords where their descendants continue to live. *Quilombos* are a symbol of black resistance. The fungus-harvestmen interactions were observed at the Quilombo Nazaré. *quilombola* is used here as an indeclinable noun in apposition.

Description: Male holotype (Col. UFPB-OP901), (Fig. 1–2, 4A).

Dorsum: Prosoma with six tubercles; ocularium smooth; dorsal scutum rectangular, iota *sensu* (Kury & Medrano, 2016); lateral margin with a row of small tubercles from coxa III to the posterior margin; area I divided by a median groove, with two tubercles each half; area II undivided with seven tubercles; area III undivided, with one pair of large spines, with apexes slightly curved backwards, posterior row with four tubercles; posterior margin with five tubercles; free tergite I with five tubercles; free tergite II with seven tubercles; free tergite III with seven tubercles; anal operculum with two rows, anterior row with four small tubercles, posterior row with three small tubercles.

Venter: Coxa I–II with two rows of small setiferous tubercles equidistant; III–IV with sparsely placed, small, setiferous tubercles; posterior margin with one row of medium, setiferous tubercles; free sternites with a row of small granules.

Chelicera: robust in males, **segment I** with three dorsal tubercles, ectal larger; **II** with median strong tubercle, 15 juxtaposed minute teeth, and four median distal teeth, and **III** with two tubercles (a basal large one and a median strong one) and two distal teeth; **inter chela space** present.

Pedipalp: long and thin; **coxa** long, with two ventral and three dorsal (one mesal and two ectal) tubercles; **trochanter** inflated, with a ventral tubercle; **femur** smooth, slightly curved inwards at the base; setation: **left tibia,**

ectal: IIiIi, mesal: IIiIi; **right tibia,** ectal: IIiIi, mesal: IIIIi; **left tarsus,** ectal: iIiIi, mesal: IiIii; **right tarsus,** ectal: iIiI, mesal: IiIii.
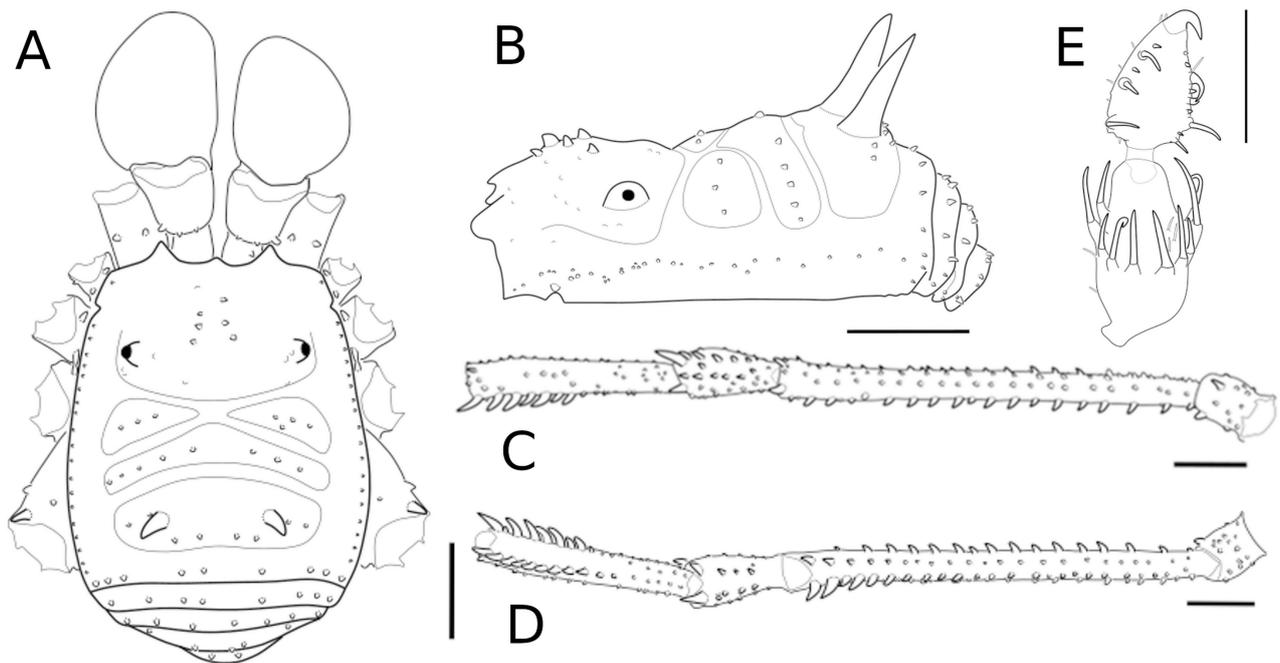

FIGURE 1. Schematic drawing of *Auranus quilombola* **sp. nov.** (Holotype, UFPB OP-901), showing main external characters. A) Dorsal habitus, B) Lateral view of the body, C) Dorsal view of left leg (trochanter, femur, patella, and tibia), D) Ventral view of left leg (trochanter, femur, patella, and tibia), E) Right pedipalp (tibia and tarsus). Scale = 1 mm.

Legend
stylus
MS A
MS C
MS D
MS E

FIGURE 2. Penis of *Auranus quilombola* **sp. nov.** (Holotype, UFPB OP-901), dorsal view on the left, lateral view at the center, and ventral view on the right. Details of macrosetae are shown with colors. Scale = 0.25 mm.

Legs: **coxa I–II** with two tubercles, anterior and posterior; **II** with a strong, posterior tubercle fused with the anterior one, at the apex near the lateral margin of the scutum**; III** with anterior tubercle fused at apex to the posterior one of coxa II; **IV** with three dorsal, sparsely placed tubercles; **trochanter I–IV** with each with four ventral, sparsely

placed tubercles, basal one larger; **II** and **III** with two minute apical tubercles (pro and retrolateral) and two dorso-apical posterior tubercles; **II** with a minute basal retrolateral tubercle; **III** with a dorso-apical anterior tubercle; **IV** with two dorso-apical and two dorso-ectal tubercles small and similar in size, and two large tubercles (pro and retrolateral); femora with tubercles organized in five rows (two ventral, two dorsal, and one retrolateral) and two dorso-apical tubercles; **III** with two ventral rows of tubercles, increasing in size apically; **IV** with a retrolateral row of large, basal tubercles, a ventro-ectal row of tubercles extending throughout the femur, a ventro-mesal row with tubercles extending from basal third to the apex; ventro-ectal apical large pointed tubercle; **patella I** and **II** unarmed; **III** with two dorso-apical tubercles, one large pointed and the other reduced; **IV** with two dorso-apical tubercles larger than those of femur IV and one large ventro-ectal, apical tubercle; **tibia I–III** with dorsal and ventral rows of small tubercles; **IV** with two rows of pointed ventral tubercles, increasing in size towards the apex; **metatarsus I** unarmed; **II–IV** with a pair of ventro-apical large and strong setae; **tarsal process** present, with one-third the size of the claws; **claws** smooth; **tarsal segmentation:** 7, 14, 6, 7.

Penis (Fig. 2): Calyx short and thin, more curved apically. Malleus wide and swollen, clearly separated from the calyx; chaetotaxy: MS A: A1 inserted latero-dorsally on malleus, A2–A3 inserted laterally on malleus; MS B: reduced; MS C: two-three pairs cylindrical, curved, and sharp, placed laterally on calyx; MS D: reduced; MS E: reduced; glans membranous, stylus long, dorsally curved, with a wide apex forming a keel; dorsal process long and thin; truncus inflated distally with a constriction on the apex, separated from malleus.

Coloration: General brown. Prosoma dark brown with lighter spots; abdominal scutum dark brown with lighter sulci. Pedipalps and chelicerae yellowish with dark reticulation on dorsal palps, tibia, and tarsus. Coxae and trochanters of legs orange with lighter apexes, other segments of legs brown. Free tergites dark with orange stripes.

Measurements: Length of dorsal scute: 3.47; width of dorsal scute: 3.24; interocular distance: 1.51; length of pedipalp: 7.13; length of leg I: 12.44; leg II: 26.77; leg III: 18.06; leg IV: 24.83.

Variation in males (n=10): Length of dorsal scute: 3.26–3.89; width of dorsal scute: 2.73–3.41; interocular distance: 0.95–1.62; length of pedipalp: 7.13–8.23; length of leg I: 11.52–14.63; leg II: 24.75–31.14; leg III: 16.88–22.04; leg IV: 22.35–31.35. Pedipalp setation: tibia mesal: IiiIi, IIiII, IiiIi, ectal: IiiIi, IiiII, IIiII, IIiIi; tarsus mesal: IiIiIi, iiIiIi, IiIii, Iiiii, ectal: iIiiiIii, iIiiiIiii, iIiiiIiII, iIiii, iIiIiiiI, iIiIii, iIiIi. Tarsal segmentation: 6–7, 14–17, 6–7, 6–7.

Sexual dimorphism: Visible with respect to size of chelicerae and armature of legs. Females have smaller chelicerae, and their legs are less armed in comparison to males, and absence of rows of ventral tubercles on tibia IV in the females.

Variation in females (n = 12): Length of dorsal scute: 3.27–3.92; width of dorsal scute: 2.69–3.74; interocular distance: 0.89–1.55; length of pedipalp: 6.46–7.77; length of leg I: 10.28–12.28; leg II: 22.79–27.59; leg III: 15.43–19.6; leg IV: 20.46–25.69. Pedipalp setation: tibia mesal: IiiIi, IIiIIi, IIiII, IIiIi, ectal: IIiIi, IIiII, IiiIi; tarsus mesal: IiIiIi, ectal: iIiiiIi, iIiiiIii, iIiiIi. Tarsal segmentation: 7, 14–17, 5–6, 6–7.

Type locality: BRAZIL. Ceará. Guaramiranga. Parque das Trilhas (4.25˚S, 38.93˚W)

Geographic distribution (Fig. 3)**:** BRAZIL. Ceará (Baturité, Guaramiranga, Itapipoca, Maranguape, Pacatuba, Pacoti, Ubajara). Montane and submontane humid forests (*brejos de altitude*) of Baturité, Maranguape, Aratanha, Uruburetama, and Ibiapaba mountain slopes.

Field note: *Auranus quilombola* **sp. nov.** is found abundantly in all the localities from where the specimens were collected (there are no quantitative data, but its abundance is reflected in the high numbers of deposited specimens; refer to "Type Material" above). The individuals are very quick and agile, a distinct behavior when compared to harvestmen species in general.

Fungus-harvestmen interactions

In total we collected 89 harvestmen belonging to the species *Auranus quilombola* **sp. nov.** (Fig. 4A), of which 22 individuals were infected by the fungus *Gibellula* sp. (Fig. 4). Maximum portions of the bodies of the infected harvestmen were covered with yellowish-orange mycelium (Fig. 4B, C), from which numerous fruiting bodies (perithecia) grew. These perithecia were flask-shaped and had light brown coloration at the base and orange coloration at the top (Fig. 4C). The perithecia grew in a scattered manner, either solitary or in small groups (Fig. 4C).
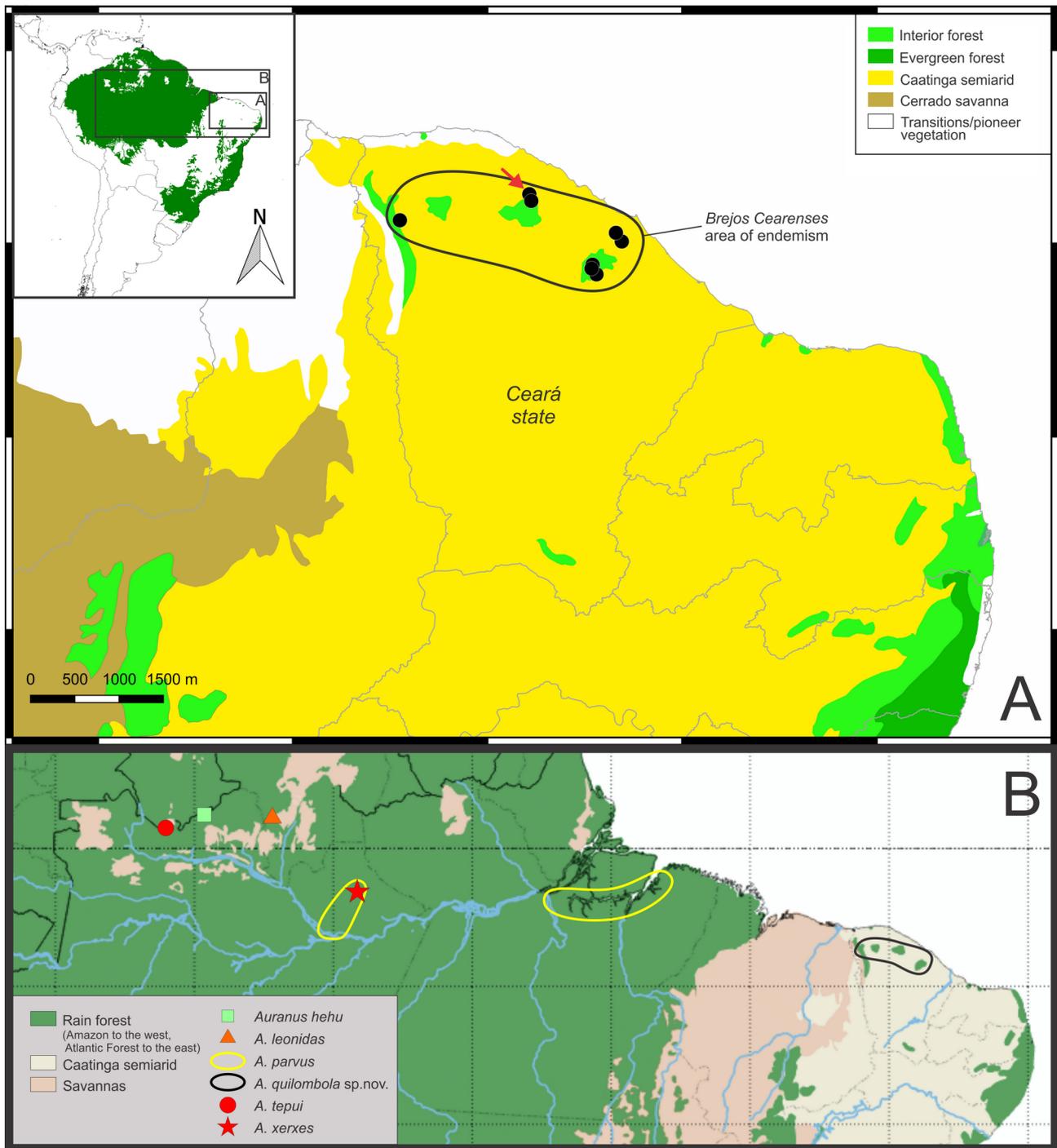
FIGURE 3. Distribution map of *Auranus quilombola* **sp. nov.** and other *Auranus* species. A) Records of *A. quilombola* **sp. nov.** in *Brejos de Altitude* of Ceará state. Black dots are the known records, red arrow is the location of observation of fungus-harvestmen interaction, full line is the *Brejos Cearenses* area of endemism delimitation. B) Distribution of *Auranus* species in the Amazon forest according Colmenares *et al.* (2016) and the new species in Atlantic forest. In detail, South America with the two great blocks of rain forest, Amazonian and Atlantic forest, showing the geographic locations of A and B.
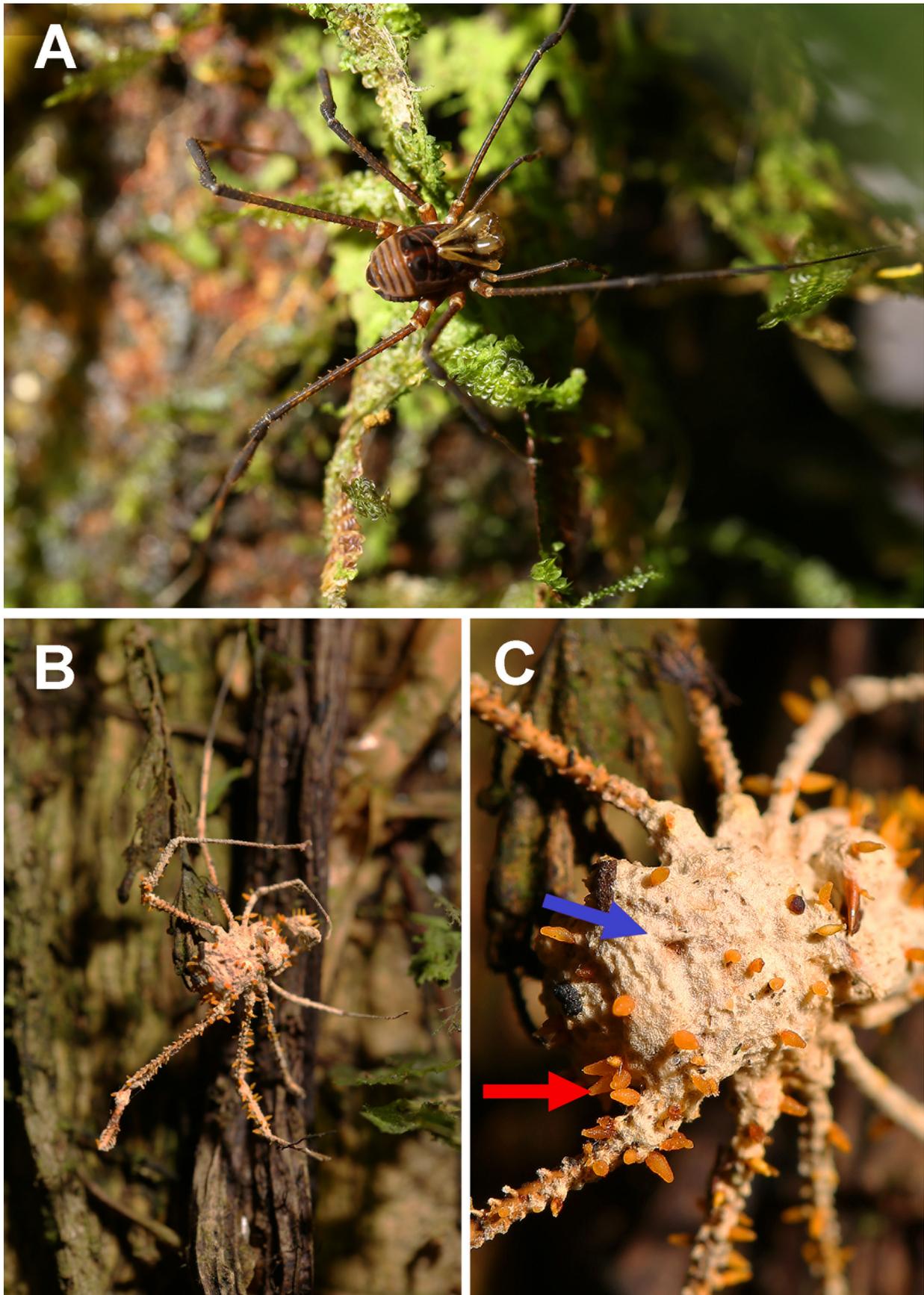
FIGURE 4. Fungus-harvestman interaction. A) Habitus of male *Auranus quilombola* **sp. nov.** without fungus infection. B) *A. quilombola* **sp. nov.** male, parasitized by arthropod-pathogenic fungus *Gibellula* sp. C) Details of the fungus *Gibellula* sp. parasitizing the harvestman *A. quilombola* **sp. nov.** (blue arrow shows the mycelium; red arrow shows the perithecium).

Discussion

Systematics and Biogeography

With the discovery and description of *Auranus quilombola* **sp. nov.**, the genus *Auranus* now encompasses six species, five of which live in the Amazon Forest, and the new species described here is the first to occur outside the Amazon biome. The new species is included in the genus *Auranus* based upon the putative synapomorphies of the genus: three areas in the dorsal scutum, trochanter IV with a large, dorsal tubercle (Pinto-da-Rocha & Villarreal Manzanilla 2009), and penis with a thin *lamina parva* as a calyx inserted in a swollen malleus (Colmenares *et al.* 2016). The closely related genera *Jabbastygnus*, *Stenostygnoides,* and *Verrucastygnus* have been studied and they have been found to have some important morphological distinctiveness (Pinto-da-Rocha 1997; Kury & Villarreal 2015; Colmenares *et al.* 2016). Moreover, they do not share the synapomorphies of *Auranus*; hence, the present taxonomic hypothesis is considered to be robust. This can be further tested with comprehensive phylogenetic studies using both morphological and molecular data.

Brejos de altitude are enclaves of humid montane forests among the scrublands of the Caatinga, a semi-arid ecosystem that covers the northeast region of Brazil. These enclaves cover the tops of mountains that are higher than 600 m of altitude, where humidity and orographic rainfall are constant. The *brejos de altitude* harbor a large number of forest-dependent and endemic species that are related to the tropical forests in the western Amazon and eastern Atlantic regions (Tabarelli & Santos 2004; Silveira *et al.* 2019). *Brejos* in the western part of Ceará state (called *Brejos Cearenses*) form an area of endemism for harvestmen (DaSilva *et al.* 2016; DeSouza *et al.* 2017). Relationships among the various components of the *brejos de altitude* montane forests, including both Amazon region and northeastern Atlantic forest (Tabarelli & Santos 2004; Silveira *et al.* 2019), have been established mainly by using the inferences derived from the floristic similarity data (Santos *et al.* 2007; Silva-de-Miranda *et al.* 2018) and the population genetic structures (d'Horta *et al.* 2011) of these regions. The relationship between *Auranus quilombola* **sp. nov.** and the pre-existing Amazonian *Auranus* species is a new piece of evidence for the connection between *Brejos Cearenses* and Amazonia (Batalha-Filho *et al.* 2013); moreover, it is also considered that forest-dependent taxa, such as *Auranus*, have isolated and diversified themselves as a result of the expansions of the Caatinga and Cerrado ecosystems in the past.

The endemism of the species found in the *Brejos Cearenses* has been corroborated as new data were published on the biota of this region (e.g., Hoogmoed *et al.* 1994; d'Horta *et al.* 2011; Fernandes-Ferreira *et al.* 2015). With respect to harvestmen, at least seven range-restricted species are endemic to the humid forests of Baturité, Pacatuba (Aratanha), Maranguape, Uruburetama, Meruoca, and Ibiapaba mountains, and there are a total of 17 recorded species from these mountains (DaSilva *et al.* 2016, DeSouza *et al.* 2017, Silvino *et al.* in prep., Saraiva *et al.* in prep.). *Auranus quilombola* **sp. nov.** range exactly matches the Congruence Core of *Brejos Cearenses* area of endemism (DaSilva *et al.* 2016) formed by these mountainous forests. *Protimesius orcus* (Villarreal *et al.* 2019; non-published records from UFPB collection) and five undescribed species of Zalmoxidae, Cosmetidae, and Gonyleptidae are also endemic to this Congruence Core.

The new species is a good model for studies on the biogeographical evolution of *Brejos Cearenses* as it is a commonly found species in these forests. It is a good candidate for studying the historical, biogeographic, and phylogeographic relationships between *Brejos Cearenses* and the Amazonia forests, a topic that has very few reports in the literature.

Fungus-harvestmen interactions

The genus *Gibellula* sp. consists of pathogenic fungi whose hosts are usually spiders. This study is the first to document a harvestman as the host for *Gibellula* sp. Several of the host spider species of *Gibellula* sp., recorded to date, are adult individuals from the family Salticidae (Evans & Samson 1987; Samson & Evans 1992), and recently, a new species of ghost spider of the family Anyphaenidae has also been included (Brescovit *et al.* 2019; Arruda *et al.* 2021). However, in many records, the host has been described as an "unidentified spider" (Johnson *et al.* 2009), which limits our knowledge about the host-specificity of the pathogenic fungus . A similar case had occurred with fungi of the order Laboulbeniales. These fungi were known to be insect and mite-exclusive pathogens (Balazuc 1990; Santamaria *et al.* 2016), but in 2015, three species of the harvestman *Dicranolasma* were reported as their new hosts. It turned out that these species of harvestmen live in litter where the humidity is generally high, which is compatible with the general preferences of Laboulbeniales fungi (Santamaria *et al.* 2017).

In literature, the terms entomopathogenic or arthropod-pathogenic fungi are commonly used to refer to the fungi that attack arthropods (e.g. Møller 1993; Roy *et al.* 2006; Barbosa *et al.* 2016). We propose to use the term entomopathogenic only for those genera of fungi that exclusively attack insects. With respect to the genus *Gibellula*, the hosts may be spiders, harvestmen, or insects; hence, the term arthropod-pathogenic is appropriate in this case. This classification would be suggested for the genus level of the fungus because there are few papers addressing fungus-arthropod interactions at the species level to be able to determine whether the particular fungus species is specific for a particular arthropod host. Hence, more studies need to be carried out on fungus-arthropod interactions so that the degree of host-specificity of these pathogenic fungi can be determined, with respect to their arthropod hosts.

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