



## First record of *Hirsutella saussurei* in the Galápagos Islands and first evidence parasitizing the invasive paper wasp, *Polistes versicolor*

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### ABSTRACT

In the present work we report the first occurrence of the entomogenous fungus *Hirsutella saussurei*, in the Galápagos Islands, and also the first evidence of this fungus parasitizing a new host: the invasive paper wasp *Polistes versicolor*. Some wasps parasitized by the fungus were found in Santa Cruz island in 2018 and 2019, while two new specimens were found in Floreana in 2019. Our data enlarge both the geographical distribution of the fungus and the host range. Even though *P. versicolor* is considered an important threat for the Galapagos endemic fauna, it is necessary a deep research to know if *H. saussurei* could be included under control programs of this invasive wasp.

*Hirsutella* (Ascomycota: Hypocreales) is a pathogenic genus of fungus that can infect different groups of insects and comprises a large number of species (Ferron, 1978). In the Galápagos Islands, *Hirsutella* spp. have been described infesting several groups of insects (Evans and Samson, 1982; Iturriaga, 2014). In the literature, *Hirsutella saussurei* (Cooke) Speare (Ascomycota: Hypocreales) has been recorded from several countries parasitizing both *Polistes* (Hymenoptera: Vespidae) and other vespid wasps (Vosseler, 1902; Speare, 1920; Petch, 1924, 1948; Mains, 1951; Tanada, 1956; Ulloa and Benavides, 1991; Tzean et al., 1997; Rose et al., 1999; Van Vooren and Audibert, 2005; Luangsa-ard et al., 2008; Montalva et al., 2017), although the *Polistes* hosts are only described in a few studies: *Polistes americanus* (Fabricius) (Cooke, 1892) latter considered as synonymous name of the species *Polistes crinitus* (Felton) (Carpenter, 1996), *Polistes rubiginosus* Latreille (Mains, 1951), *Polistes annularis* Linnaeus (Speare, 1920) and *Polistes olivaceus* DeGeer (Van Vooren and Audibert, 2005).

In 2018, we detected an entomogenous fungus parasitizing *Polistes versicolor* (Olivier) (Hymenoptera: Vespidae) on Santa Cruz (Galápagos

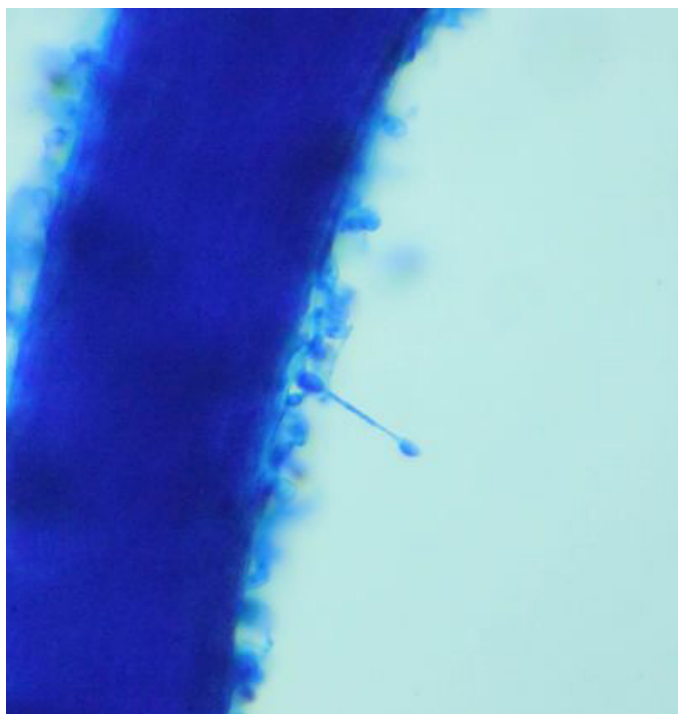
Islands, Ecuador) on two occasions. The first infected wasp was found on a coffee leaf *Coffea arabica* L. (Gentianales: Rubiaceae) in August (UTM 15 S 797829 9924188), and the second specimen was found on a corn plant *Zea mays* L. (Cyperales: Poaceae) in October (UTM 15 S 797670 9924352), both in an agricultural field at Bellavista on Santa Cruz. Both wasps had synnemata arising from various parts of the body (Fig. 1). The parasitized specimens were collected, and fungus was identified as *H. saussurei*. Some preparations of the hyphae and phialides of the fungus were deposited in the Entomological Collection of ESPOCH. The first diagnosis of *H. saussurei* was made by Cooke (1892) who identified the species under the provisional name of *Isaria saussurei* based on the Saussure's illustration (Saussure, 1858). Speare (1920) provided the first description of *I. saussurei* as *Hirsutella saussurei*. Our specimens were identified as *H. saussurei*, based on the morphology of the hyphae and phialides (Fig. 2), according to those described by Mains (1951). *Hirsutella saussurei* is characterized by synnemata aerial or procumbent and appressed to the substratum, arising from various parts of the body and appendages of the host (Fig. 1), slender,

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**Figure 1.** Synnemata of *H. saussurei* (Cooke) Speare (Ascomycota: Hypocreales) arising from host (*P. versicolor* (Olivier) (Hymenoptera: Vespidae)), picture was taken during a sampling at Cerro Luna, in Santa Cruz (Galápagos, Ecuador). It is possible to observe the hyphae of the fungi arising from some parts of the wasp body.



**Figure 2.** Phialidae (conidia attached at the apical part of the sterigmata) of *H. saussurei* (Cooke) Speare (Ascomycota: Hypocreales) from our sample, photographed using a digital camera attached to a microscope (1000 X) and previously dyed with blue of lactophenol.

terete, somewhat attenuated upward, very variable in length, 1-7 mm long. 0.1-0.3 mm thick, light brown, composed of closely compacted, parallel, longitudinal, and 2-4  $\mu$  wide hyphae; phialides scattered to moderately crowded, arising as lateral cells or buds from the outer hyphae of the synnema or as terminal cells of short lateral branches, the lower portions cylindrical, obovoid or ellipsoid, 7-16  $\times$  3-6  $\mu$ , attenuated above into slender sterigmata 10-40  $\mu$  long (Fig. 2) (Mains,

1951). To our knowledge the two infested wasps constitute the first report of *H. saussurei* for the Galápagos Islands. This is also the first report of the fungus parasitizing a new host: *P. versicolor*.

In July 2019, after the identification of the fungus, we found five individuals of *P. versicolor* parasitized by *H. saussurei* at Cerro Media Luna (UTM 15S 797762 9926274), in the humid zone of Bellavista (Santa Cruz). Two additional individuals were found in the humid zone of Floreana (UTM 15S 783488 9856168) suggesting that the fungus can spread to other islands.

All wasp specimens were found dead laying on a vegetable substrate. New studies described the ability of this fungus to manipulate their wasp host on different ways to place the host in a suitable location for the fungal development and dispersion (Somavilla et al., 2019). Sexual (*Ophiocordyceps humberitii* (Ascomycota: Hypocreales)) and asexual (*H. saussurei*) stages of the fungus develop onto understory vegetation when nests are swarm-founding wasp species while only asexual stage of the fungus is developed in independent-founding wasp species (Somavilla et al., 2019).

The distribution of the paper wasp, *P. versicolor*, ranges from Costa Rica to Argentina (Richards, 1978). In the Galápagos Islands, *P. versicolor* was first recorded in 1988, probably introduced from a cargo-ship transporting fruits such as bananas (Abedrabbo, 1991). This wasp is highly invasive (Causton et al., 2006) and its predatory behavior has a negative impact on endemic species of the Galápagos Islands by preying on larvae of other insects (Parent, 2000). For a density of three nests per 100 m<sup>2</sup>, *P. versicolor* can prey upon 154.5 g of insects per hectare per day, mainly Lepidoptera larvae (46% of prey) (Parent, 2000). This preference for caterpillars was observed in other studies. In Brazil, Prezoto et al. (2006) observed that 95.4% of the prey of *P. versicolor* was Lepidoptera larvae. Since caterpillars are one of the most important resources for some species of Darwin's finches in the breeding season (Boag and Grant, 1984) and other insectivorous animals; *P. versicolor* has become a significant competitor of the native Galápagos fauna (Parent, 2000).

The negative impact of *P. versicolor* on the Galápagos Islands' biodiversity makes necessary the implementation of an urgent action plan to control its population. The use of pesticides could harm non-target organisms, both arthropods and vertebrates (Desneux et al., 2007; López et al., 2012), and the environment. Therefore, strong emphasis should be placed on implementing environmentally safe measures such as biological control.

Since the detection of *P. versicolor* in the Galápagos Archipelago, some natural enemies have been reported exploiting it as prey or host. Lasso (1997) found two species of Lepidopteran (*Erechtias minuscula* (Walsingham) (Lepidoptera: Tineidae) and possibly *Holocera* sp. (Lepidoptera: Blastobasidae)) parasitizing nests of the wasp. In addition, Parent (2000) reported the presence of the predatory moth *Taygete sphecochila* (Meyrick) (Lepidoptera: Autostichidae) in some nests of *P. versicolor*, the highest percentage of predation was found in the humid area of Floreana, and it was low (only 58.7% of sampled nests showed evidence of predation by the moth). All these natural enemies contribute to reduce *P. versicolor* populations, but due to the high population of *P. versicolor* observed their action has had little impact. Therefore, searching for effective additional natural enemies of this invasive wasp has become an imperative task to reduce its population and its negative impact in the islands.

Although *H. saussurei* has been reported mainly infecting vespids (both *Polistes* spp. and *Vespula* spp.), and could be good candidate to include in the Integrated Pest Management Program of the invasive paper wasp *P. versicolor* in the Galápagos Islands, further work is needed to ascertain whether this fungus could have negative impact on endemic fauna of the Archipelago, before making a conclusion.

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## Conflicts of interest

The authors declare there is no conflicts of interest.

## Author contribution statement

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Óscar Mollá. First identification of the fungus was made by Óscar Mollá and confirmed by Bhushan Shrestha. The first draft of the manuscript was written by Óscar Mollá and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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