

NATURALIZATION OF THE BODHI FIG TREE (*Ficus religiosa* L. - Moraceae) IN BRAZIL

NATURALIZAÇÃO DA FIGUEIRA-DOS-PAGODES (*Ficus religiosa* L. - Moraceae) NO BRASIL

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ABSTRACT: *Ficus religiosa* L. is one of the most valued cultivated ornamental fig trees. Native to Asia, it is known as Bodhi tree. Since fig trees are involved in a highly species-specific pollination mutualism with agaonid wasps, exotic fig species usually fail to produce seeds due to the lack of the specific pollinating wasps. Since 2005 we have been observing plantlets of *F. religiosa* growing on buildings in Rio de Janeiro city, Brazil, showing that this species was hosting pollinating wasps and, consequently, undertaking sexual reproduction outside its native range. We observed that *Platyscapa quadraticeps* Mayr, 1885, the original pollinator in Asia, was occurring in figs of *F. religiosa* in Brazil. Considering that several non-pollinating fig wasp species are associated with *F. religiosa* in its native areas, novel occurrences of wasps may be reported in the future in Brazil. The presence of the native pollinator provides conditions for this exotic tree to become naturalized and/or invasive in Brazil, potentially causing considerable damage to buildings and urban trees.

KEYWORDS: Agaonidae. Alien species. Fig wasp. Mutualism. Pollination.

INTRODUCTION

There are over 750 species of fig trees (*Ficus* spp., Moraceae), many of them employed as ornamental plants, especially those of the subgenus *Urostigma* Miq., the most diverse group in the genus (BERG, 1989). Fig trees have highly adapted inflorescences, defined by an enclosed inflorescence, the syconium, which is also the arena for interactions with fig wasps. Each fig has its own pollinating wasp species (sometimes more than one) from the family Agaonidae, upon which it depends for pollination (COOK; RASPLUS, 2003). Successful biological invasion by a *Ficus* species thus involves co-invasion by its symbiont pollinator. Generally, fig wasps disperse (or are introduced by man) to an area where their host fig tree has been planted. Therefore, towns and cities may act as centers of establishment for *Ficus* spp. from outside the area (McPHERSON, 1999).

The Asian fig tree *Ficus religiosa* L., known as Bodhi tree, is revered by Buddhists because Siddhartha Gautama was enlightened underneath it while in meditation (MULLER, 1999). Around the world, *F. religiosa* has been introduced as an ornamental tree. Specifically in Brazil, it was introduced in the urban landscaping of Rio de Janeiro at the end of the 19th century (CARAUTA; DIAZ, 2003) with other fig species from the Old World (e.g., *F. benjamina* L., *F. microcarpa* L., *F.*

lutea Vahl. and *F. sycomorus* L.). *Ficus religiosa* is pollinated by *Platyscapa quadraticeps* Mayr, 1885 in its native range. Its mature figs measure 10-15 mm in diameter, are red in color, and are dispersed by birds (SHANAHAN et al., 2001). *F. religiosa* has become naturalized in the United States (Florida), Hong Kong, Israel, South Africa and Zambia because its pollinator was successful in colonizing these areas (GALIL; EISIKOVITCH, 1968; NADEL et al., 1992; CORLETT, 2006; van NOORT et al., 2013). The occurrence of insect galls in flowers of *F. religiosa* has been reported in Brazil since the 1980's, without delving into insect identification (NEVES; ISAIAS, 1987).

Most of the exotic fig trees introduced in urban landscaping do not reproduce sexually due to the lack of their natural pollinators. *Ficus microcarpa* was the first fig tree to spread naturally in the Neotropical environment (FAIRCHILD, 1938) by the acclimation of its specific pollinator, *Eupristina verticillata* Waterston, 1921, registered as introduced in North America (NADEL et al., 1992; BOUČEK, 1993), and in the early 1990s, in Brazil (FIGUEIREDO et al., 1995). Non-pollinating fig wasps of *F. microcarpa* were also reported in the Neotropics coincidentally with the arrival of the pollinators *Walkerella microcarpae* Bouček 1993 (RAMÍREZ; MONTERO, 1988; FIGUEIREDO; MOTTA-JUNIOR, 1993); *Philotrypesis emeryi* Grandi, 1926, *Philotrypesis taiwanensis* Chen,

1999, and *Odontofroggata ishii* Wiebes, 1980 (FIGUEIREDO et al., 1995; FARACHE et al., 2009). The new occurrence of these wasp species confirmed the naturalization of *F. microcarpa* in cultivated fig trees in urbanized areas. However, there is still no record of *F. microcarpa* invading natural forests in Brazil.

In this study, we reported the occurrence of *Platyscapa quadraticeps* in *F. religiosa* fig trees in Rio de Janeiro, Brazil, and the subsequent spread of plantlets of this species on walls, roofs and other urban constructions.

MATERIAL AND METHODS

We studied introduced fig trees in urban areas because *F. religiosa* has not yet invaded forested habitats. We sampled figs prior to wasp emergence in three *F. religiosa* trees (a total of 138 figs) in Rio de Janeiro city, Rio de Janeiro State, Brazil (22°59'00"S, 43°13'40"W), in May and September 2007. Figs were placed in a 500 mL jar covered with voile cloth for wasp emergence. Wasp identification was based on the taxonomical literature (van NOORT; RASPLUS, 2010) and on comparison to specimens of *P. quadraticeps* collected in the Xishuangbanna Tropical Botanical

Garden, Yunnan, China. Voucher specimens are stored in the RAS Pereira collection, University of Sao Paulo, Ribeirão Preto. The identification of *Ficus religiosa* was based on published taxonomical keys and original specific descriptions, and its voucher is stored in the herbarium of Museu Nacional (R), Rio de Janeiro, Brazil.

Photos of the fig wasps were taken with a Leica MZ16 stereoscope equipped with a DFC320 digital camera. We used CombineZM software to produce the automontage images.

RESULTS

Plantlets of *F. religiosa* have been found on walls, roofs and other urban constructions in Rio de Janeiro city, Brazil (Figure 1). Pollinating agaonid *Platyscapa quadraticeps* wasps (Figure 2), the original pollinators of *F. religiosa* in Asia, emerged from all fig samples at the site under study. The occurrence of these wasps confirms the naturalization of *F. religiosa* in urbanized areas. However, there is still no record of *F. religiosa* invading natural forests in Brazil. In addition, plantlets of *F. religiosa* growing naturally in urban areas have been observed in São Paulo city, Brazil (AFP Machado, unpublished data).



Figure 1. Plantlets of *Ficus religiosa* L. sprouting through a wall in Rio de Janeiro.

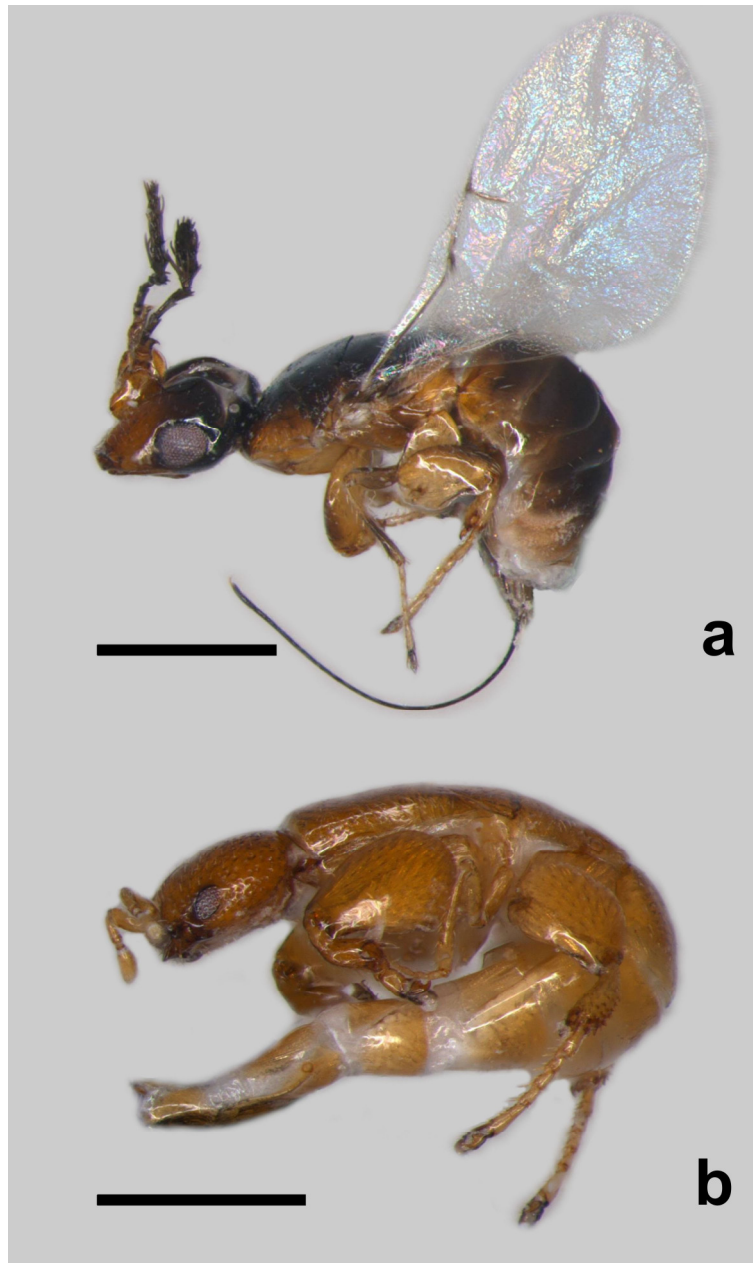


Figure 2. Specimens of *Platyscapa quadraticeps* Mayr, 1885 collected from *Ficus religiosa* L. in Brazil, (a) female, (b) male. Scale bar = 0.5 mm.

DISCUSSION

Ficus religiosa has been introduced in various locations throughout Africa, Australia/Pacific region, North America, Europe, South America and the Middle East as an ornamental tree. Where the specific pollinating wasp is not present, *F. religiosa* has been propagated through cuttings. However, the agaonid pollinator is present in the United States (Florida), Hong Kong, Israel, South Africa and Zambia and *F. religiosa* reproduces sexually through seeds (GALIL; EISIKOVITCH, 1968; PIATOS, 1975; NADEL et al., 1992; CORLETT, 2006; van

NOORT et al., 2013). Plantlets of *F. religiosa* were observed in 2006 growing spontaneously on walls in Santo Domingo city, Dominican Republic, Central America (RAS Pereira, unpublished data), indicating that the species is reproducing sexually in this area. Additionally, *P. quadraticeps* has been reported in Iraq and the United Arab Emirates, but no further information about *F. religiosa* reproduction is available (van NOORT; RASPLUS, 2010). Our results suggest that *P. quadraticeps* has recently arrived in Brazil, because it was only recently that seeds were registered in syconia and juvenile trees have been found on many urban walls and rooftops, often more than 1 km away from adult

F. religiosa trees. Considering the reports of *F. religiosa* plantlets in the 1970-1980's in Florida and in the 2000's in the Dominican Republic, *P. quadraticeps* was probably introduced in Brazil via North and Central America. Thus, the model of *F. religiosa* naturalization seems to be similar to that reported for *F. microcarpa* in the Americas (NADEL et al., 1992; FARACHE et al., 2009). Indeed, *Ficus religiosa* pollinators very probably have followed their host species outside their native range, as reported for *F. microcarpa* (WANG et al., 2015). However, in contrast to the naturalization of *F. microcarpa*, the pollinator was the first species to arrive in *F. religiosa* in Brazil, whereas non-pollinating fig wasp species were the first colonizers of *F. microcarpa* trees (FIGUEIREDO et al., 1995). This difference in colonization and the wide range of non-pollinating fig wasps introduced with *F. microcarpa* suggest that the introduction of *F. religiosa* and *F. microcarpa* in the Neotropics followed different patterns. The fact that non-pollinating fig wasp species have not been reported in *F. religiosa* in the Neotropics (although many species do occur in its native range) could indicate that its plants were transported by man without their figs, and consequently without the wasps they contain. The pollinator *P. quadraticeps*, in contrast,

followed their host trees probably due to the exceptional ability of pollinating fig wasps to disperse over long distances carried by the wind (AHMED et al., 2009).

Taking into account the diversity of fig wasps that inhabit *F. religiosa* figs in their natural distribution (WIEBES, 1966), and the gradual influx of fig wasps in other exotic fig trees (e.g. *F. microcarpa*) in Brazil (FARACHE et al., 2009), new occurrences of non-pollinating fig wasps will probably be reported in the future for *F. religiosa*. On the other hand, the naturalization of both *F. religiosa* and *F. microcarpa* in Brazil shows the importance of monitoring the reproduction of exotic fig trees. The early detection of influx of the original pollinators is crucial for defining management programs aiming to minimize the impact of invasive fig trees, which are difficult to control.

ACKNOWLEDGMENTS

MDMVF was supported by CNPq (Post-Doctoral grant #160126/2012-6), RJVA by CNPq (grant #311429/2009-2), and RASP by Fapesp (grant #04/10299-4) and CNPq (grant #306078/2014-7). We thanks Elettra Greene for the English revision.

RESUMO: *Ficus religiosa* L. é uma das figueiras ornamentais mais valorizadas. Nativa da Ásia, é conhecida popularmente como figueira-dos-pagodes. Como as figueiras apresentam um mutualismo especializado com vespas Agaonidae as espécies exóticas geralmente não se reproduzem sexualmente devido a falta dos polinizadores específicos. Desde 2005 nós observamos plantas jovens de *F. religiosa* crescendo sobre construções na cidade do Rio de Janeiro, Brasil, indicando que esta espécie está interagindo com vespas polinizadoras e, conseqüentemente, se reproduzindo sexualmente fora de sua área nativa. Observamos que *Platyscapa quadraticeps* Mayr, 1885, o polinizador original na Ásia, estava ocorrendo em figos dessa espécie no Brasil. Considerando que várias espécies não-polinizadoras de vespas de figo são associadas a *F. religiosa* em suas áreas nativas, novas ocorrências de vespas podem ser relatadas no futuro no Brasil. A presença do polinizador nativo provem condições para que esta espécie exótica se naturalize e/ou se torne invasiva no Brasil, com grande potencial de causar danos em prédios e árvores urbanos.

PALAVRAS-CHAVE: Agaonidae. Espécies invasoras. Mutualismo. Polinização. Vespa de figo.

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