Revista Brasileira de Entomologia 63 (2019) 101–103

SOCIEDADE BRASILEIRA DE ENTOMOLOGIA FUNDADA EM 1937

REVISTA BRASILEIRA DE
Entomologia
A Journal on Insect Diversity and Evolution

www.rbentomologia.com

Short Communication

Ant fauna associated with *Microgramma squamulosa* (Kaulf.) de la Sota (Polypodiaceae) fern galls

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ARTICLE INFO

Article history:
Received 18 September 2018
Accepted 26 February 2019
Available online 26 March 2019
Associate Editor: Ricardo Solar

Keywords:
Ecosystem engineers
Fern–insect interactions
Myrmecophily
Pteridophytes

ABSTRACT

Galls are neoformed plant structures created by cell hyperplasia and hypertrophy induced by a number of organisms, especially insects. After adult insects hatch, senescent galls may remain on the host plant and be occupied by a succession of fauna, the most important and dominant being ants. This study aimed at characterizing the ant fauna successor of stem galls induced by microlepidoptera in *Microgramma squamulosa* (Kaulf.) de la Sota (Polypodiaceae). Four collections were carried out in the municipality of Nova Friburgo, Rio de Janeiro state, Brazil. The galls were packed in plastic bags and taken to the laboratory. Ants were euthanized and conserved in 70° GL alcohol and later identified. A total of 49 stem galls were collected and analyzed, 15 containing microlepidoptera galler larvae, one a parasitoid wasp and 33 without the microlepidoptera or parasitoid (67%). Twelve of these galls (39%) contained ants. Six ant species were recorded (*Camponotus crassus*, *Crematogaster curvispinosa*, *Crematogaster sericea*, *Procryptocerus sampaioi*, *Tapinoma atriceps*, and *Wasmannia auropunctata*), all native to Brazil. Ant occupation in *M. squamulosa* seems to be associated with senescent galls due to hatching of the galler insect, which leaves a hole that allows ants to colonize it, in other words, an opportunistic domatia. Senescent galls resulting from the death of galler insects do not seem to facilitate ant occupation.

Galls are neoformed plant structures created by cell hyperplasia and hypertrophy. They can be induced by organisms such as fungi, bacteria, nematodes, mites and insects; however, the last two stand out for the gall diversity they induce in plants (Mani, 1964; Raman, 2007; Shorthouse et al., 2005). Inducers establish a parasitic relationship with the host plant, manipulating its metabolism (Mani, 1964; Raman, 2007).

Galler insects are among the most specialized and sophisticated herbivores, considered ecosystem engineers, due to their ability to structurally alter leaves, stems, roots, flowers or fruits and form new habitats (Jones et al., 1994; Wright and Jones, 2006; Cornelissen et al., 2016). Insect galls are induced by oviposition and/or development of their larvae in plant tissues (Shorthouse et al., 2005). After adult insects hatch, senescent galls may remain on the host plant and be occupied by a succession of fauna, the most important and dominant being ants (Mani, 1964; Almeida et al., 2014). Senescent galls provide shelter and a nesting site for many ant species, mainly arboreal ants (Santos et al., 2017; Almeida et al., 2014). However, in the galler-fern-ant system, the importance of ants to the gall/plant remains unclear.

In addition to shelter, some galls are a food source for many ant species. Moreover, certain galls induced by Eriophyidae, Homoptera, Hymenoptera and Diptera may produce honeydew, which attracts flying insects and ants (Mani, 1964; Washburn, 1984).

Because ferns do not have flowers, most researchers have long ignored the potential of fern-animal interactions (Watkins Jr. et al., 2008). However, these interactions may occur via herbivory (Mehltreter, 2010), with the presence of domatia (Gómez, 1974), leaf nectaries (Koptur et al., 1982), crypticity (Santos and Wolff, 2015) and galls (Santos et al., 2019).

Although they are more frequent in spermatophytes, galls can also be found in ferns and lycophytes (Santos et al., 2019). In Brazil, galls have been recorded on 16 fern species induced by mites (Eriophyidae) and insects of the orders Lepidoptera, Thysanoptera, Hemiptera and Diptera, the last being the most frequent galler represented by the Cecidomyiidae family (Santos and Maia, 2018).

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https://doi.org/10.1016/j.rbe.2019.02.004

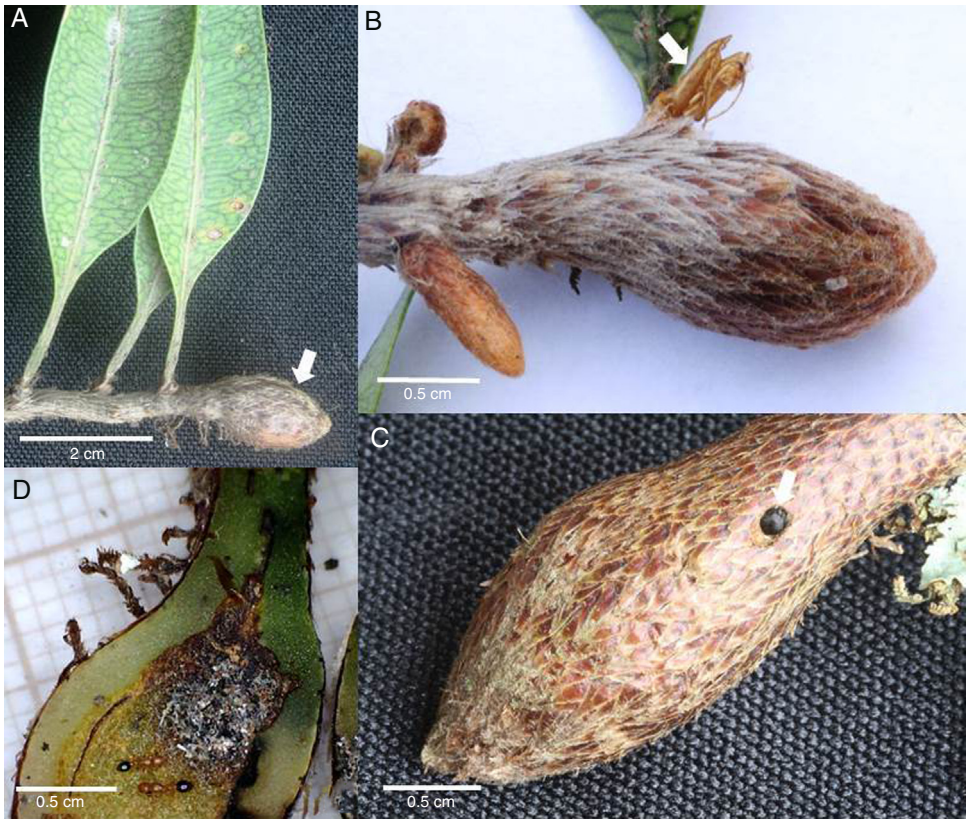

Fig. 1. (A) Stem gall on *Microgramma squamulosa* (arrow); (B) Ecdyse of the microlepidoptera galler that emerged from the gall (arrow); (C) hole left by the exiting galler (arrow); (D) sectioned gall exhibiting ants living inside.

Galls have been recorded in three *Microgramma* C. Presl (Polypodiaceae) species, *M. squamulosa* (Kaulf.) de la Sota and *M. vacciniifolia* (Langsd. & Fisch.) Copel. in Brazil (Santos and Maia, 2018), and *M. percussa* (Cav.) de la Sota in Costa Rica (Santos et al., 2019). Moreover, several species of this genus of fern contain domatia (Mehltreter, 2010).

Two gall morphotypes were recorded in *Microgramma squamulosa*, a neotropical epiphyte fern (Rocha et al., 2014). One is a stem gall (Fig. 1A) induced by *Tortrimosaica polypodivora* Brown & Baixeras, 2004 (Tortricidae: Lepidoptera) (Kraus et al., 1993; Brown et al., 2004), and the other a conical leaf gall induced by a yet-to-be-identified Cecidomyiidae (Diptera) (Santos and Maia, 2018). Both morphotypes occur in the states of Rio de Janeiro and São Paulo, Brazil (Santos and Maia, 2018). Earlier fieldwork found ants occupying senescent galls of *M. squamulosa* (Fig. 1D). As such, this short communication aims at characterizing the ant fauna successor of stem galls induced by *Tortrimosaica polypodivora* in *M. squamulosa.* The galls were collected in a forest area of the Nova Friburgo Country Club (22°17′31.6″S 42°32′25.1″W) and Praça do Suspiro (Suspiro Square) (22°16′45.8″S 42°32′08.9″W), both located in the municipality of Nova Friburgo, Rio de Janeiro state, Brazil. Collections were carried out in the dry (April 2016 and June 2017) and rainy seasons (October 2017 and February 2018), according to Barbieri's classification (2005) for the Brazilian Southeast region.

We performed an active search of trees at the two collection sites and all galls found were packed in plastic bags and sorted in the laboratory. All biological voucher material was deposited in the herbarium of the Faculdade de Formação de Professores da Universidade do Estado do Rio de Janeiro (RFFP) and the Padre Jesus Santiago Moure Entomological Collection, Universidade Federal do Paraná, Department of Zoology (DZUP).

The galls were sectioned in the laboratory and all ants euthanized and fixed in 70° GL alcohol. They were identified by Dr. Rodrigo M. Feitosa, in the Laboratory of Systematics and Ant Biology at Universidade Federal do Paraná.

A total of 49 stem galls from *M. squamulosa* were collected and analyzed, 15 containing microlepidoptera galler larvae, one a parasitoid wasp and 33 without the microlepidoptera or parasitoid (67%). Twelve of these galls (36%) contained ants and twenty-one were empty.

Six ant species, belonging to five genera were recorded (*Crematogaster*, *Camponotus*, *Procryptocerus*, *Tapinoma* and *Wasmannia*), all native to Brazil (Table 1). Except for *Crematogaster sericea*, all the ant species established nests inside galls, with both immature and sexual individuals present, indicating they are being used by colonies for shelter. Furthermore, all ants that occupied galls are arboreal, which was expected because the galls were found in an epiphytic fern (*M. squamulosa*). In relation to food habits, all the ant species observed here can be considered generalists (Baccaro et al., 2015).

The genera *Camponotus* and *Crematogaster* are among the most frequent gall successors in angiosperm galls (Mani, 1964) and inhabitants of *Microgramma* spp. (Gómez, 1974) and *Lecanopteris* spp. domatia (Gay, 1993), both genera belonging to the family Polypodiaceae.

The species with the highest frequency in galls were *Camponotus crassus* and *Procryptocerus sampaioi*, occurring in three galls each, and those with the greatest density were *Tapinoma atriceps* and *Wasmannia auropunctata* (Table 1). *Crematogaster curvispinosa* was only recorded in the rainy season, *C. sericea* and *W. auropunctata* only in the dry season, and *C. crassus*, *P. sampaioi* and *T. atriceps* were found in both seasons (Table 1).

Table 1
Ants recorded in senescent stem galls of *Microgramma squamulosa* (Kaulf.) de la Sota. Number of galls with ants ($n = 12$). Number of ants ($n = 399$).

Species	Origin	Occurrence (No. of galls)	Absolute frequency (%)	Number of ants per gall	Absolute density	Relative density (%)	Season
Crematogaster curvispinosa Mayr, 1862	Native (Longino, 2003)	2	16.67	29.5±14.8	59	14.79	Rainy
Crematogaster sericea Forel, 1912	Native (Longino, 2003)	1	8.33	4	4	4	Dry
Camponotus crassus Mayr, 1862	Native (Fernández & Sendoya, 2004)	3	25.0	14.6±6.7	34	8.52	Dry and rainy
Procryptocerus sampaioi Forel, 1912	Native (Baccaro et al., 2015)	3	25.0	8.6±6.7	8.6±6.7	6.52	Dry and rainy
Tapinoma atriceps Emery, 1888	Native (Shattuck, 1994)	2	16.67	67.5±88.4	135	33.83	Dry and rainy
Wasmannia auropunctata (Roger, 1863)	Native (Longino and Fernández, 2007)	1	8.33	141	141	35.34	Dry

According to Mehltreter, 2010, interactions between ferns and ants can be neutral or mutualistic. The presence of domatia in epiphytic ferns of the genus *Microgramma*, subgenus *Solanopteris* (Gómez, 1974; Lellinger, 1977), as well as in *Lecanopteris* (Gay, 1993), may establish a mutualistic relation with a number of ant species. However, in some situations, ants can be opportunists and inhabit organ cavities (primarily stems and petioles) of ferns produced by the action of herbivores, which Mehltreter et al. (2003) referred to as opportunistic domatia.

The possible nutritional benefits for plants promoted by these ants, especially nitrogen, remains to be assessed. For exemple, in the tissues of an epiphyte fern [*Antrophyum lanceolatum* (L.) Kaulf. – Pteridaceae], Watkins Jr. et al. (2008) found high levels of nitrogen from waste produced by the nests of ants associated with this plant. These authors suggest that animals may provide substantial nutritional benefits to plants with little or no investment, not requiring specialized structures such as domatia or leaf nectaries. Thus, the hypothesis that the nests of gall-dwelling ants supply nutritional support to the epiphyte fern *M. squamulosa* has yet to be tested.

In *M. squamulosa*, ant occupation seems to be associated with senescent galls caused by galler insect hatching (Fig. 1B), which leaves a hole (Fig. 1C) that allows ants to enter and colonize it, in other words, an opportunistic domatia (sensu Mehltreter et al., 2003). Senescent galls due to death of galler insects seem not to facilitate this occupation by ants.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

The authors would like to thank The National Council for Scientific and Technological Development (CNPq), Carlos Chagas Filho Research Support Foundation of Rio de Janeiro state (FAPERJ), and Incentive Program for Scientific, Technical and Artistic Production of Rio de Janeiro State University (PROCIENCIA-UERJ) for funding. We are also grateful to Anderson dos Santos Portugal, Arthur Flores Ribeiro and Mariana Fernandes da Rocha from the UERJ Biodiversity Teaching and Research Laboratory for help in data collection.

References

Almeida, M.F.B., Santos, L.R., Carneiro, M.A.A., 2014. Senescent stem-galls in trees of *Eremanthus erythropappus* as a resource for arboreal ants. Rev. Bras. entomol. 58, 265–272.
Baccaro, F.B., Feitosa, R.M., Fernandez, F., Fernandes, I.O., Izzo, T.J., Souza, J.L.P., Solar, R., 2015. Guia para os gêneros de formigas do Brasil. Editora INPA Manaus.
Barbieri, P.R.B., MSc Dissertation 2005. Um estudo sobre as estações seca e chuvosa nas regiões Sul e Sudeste do Brasil e sua associação com a circulação atmosférica na América do Sul. Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil.
Brown, J.W., Baixeras, J., Solorzano-Filho, J.A., Kraus, J.E., 2004. Description and life history of an unusual fern-feeding tortricid moth (Lepidoptera: Tortricidae) from Brazil. Ann. Entomol. Soc. Am. 97, 865–871.
Cornelissen, T., Cintra, F., Santos, J.C., 2016. Shelter-building insects and their role as ecosystem engineers. Neotrop. Entomol. 45, 1–12.
Fernández, F., Sendoya, S., 2004. Synonymic list of Neotropical ants (Hymenoptera: Formicidae). Biota Colombiana 5, 3–105.
Gay, H., 1993. Rhizome structure and evolution in the ant-associated epiphytic fern *Lecanopteris* Reinw (Polypodiaceae). Bot. J. Linn. Soc. 113, 135–160.
Gómez, L.D., 1974. Biology of the potato-fern *Solanopteris brunei*. Brenesia 4, 37–61.
Jones, C.G., Lawton, J.H., Shachak, M., 1994. Organisms as ecosystem engineers. Oikos 69, 373–386.
Koptur, S., Smith, A.R., Baker, I., 1982. Nectaries in some Neotropical species of Polypodium (Polypodiaceae): preliminary observations and analyses. Biotropica 14, 108–113.
Kraus, J.E., Montenegro, G., Kim, A.J., 1993. Morphological studies on entomogenous stem galls of *Microgramma squamulosa* (Kauf.) Sota (Polypodiaceae). Am. Fern. J. 83, 120–128.
Lellinger, D.B., 1977. Nomenclatural notes on some ferns of Costa Rica Panama, and Colombia. Am. Fern. J. 67, 58–60.
Longino, J.T., 2003. The *Crematogaster* (Hymenoptera, Formicidae Myrmicinae) of Costa Rica. Zootaxa 151, 1–150.
Longino, J.T., Fernández, F., 2007. Taxonomic review of the genus *Wasmannia*. In: Snelling, R.R., Fisher, B.L., Ward, P.S. (Eds.), Advances in Ant Systematics (Hymenoptera:Formicidae): Homage to E. O. Wilson – 50 Years of Contributions. Memoirs of the American Entomological Institute, vol. 80. American Entomological Institute, Gainesville, USA, p. 271-289.
Mani, M.S., 1964. Ecology of Plant Galls. Springer-Science.
Mehltreter, K., 2010. Interactions of ferns with fungi and animals. In: Mehltreter, K., Walker, L.R., Sharpe, J.M. (Eds.), Fern Ecology. Cambridge University Press, p. 220-254.
Mehltreter, K., Rojas, P., Palacios-Rios, M., 2003. Moth larvae-damaged giant leather-fern *Acrostichum danaeifolium* as host for secondary colonization by ants. Am. Fern. J. 93, 49–55.
Raman, A., 2007. Insect-induced plant galls of India: unresolved questions. Curr. Sci. 92, 748–757.
Rocha, L.D., Costa, G.M., Gehlen, G., Droste, A., Schmitt, J.L., 2014. Morphometric differences of *Microgramma squamulosa* (Kaulf.) de la Sota (Polypodiaceae) leaves in environments with distinct atmospheric air quality. An. Acad. Bras. Ciênc. 86, 1137–1146.
Santos, L.R., Feitosa, R.M., Carneiro, M.A.A., 2017. The role of senescent stem-galls over arboreal ant communities structure in *Eremanthus erythropappus* (DC) MacLeish (Asteraceae) trees. Sociobiology 64, 7–13.
Santos, M.G., Maia, V.C., 2018. A synopsis of fern galls in Brazil. Biota Neotrop. 18, e20180513.
Santos, M.G., Hanson, P., Maia, V.C., Mehltreter, K., 2019. A review of galls on ferns and lycophytes. Environ. Entomol. 48, 53–60.
Santos, M.G., Wolff, V.R.S., 2015. Two species of armored scale insects (Hemiptera: Diaspididae) associated with sori of ferns. EntomoBrasilis 8, 232–234.
Shattuck, S.O., 1994. Taxonomic Catalog of the Ant Subfamilies Aneuretinae and Dolichoderinae (Hymenoptera: Formicidae). University of California Press, USA.
Shorthouse, J.D., Wool, D., Raman, A., 2005. Gall-inducing insects – Nature's most sophisticated herbivores. Basic Appl Ecol. 6, 407–411.
Washburn, J.O., 1984. Mutualism between a cynipid gall wasp and ants. Ecology 65, 654–656.
Watkins Jr., J.E., Cardelús, C.L., Mack, M.C., 2008. Ants mediate nitrogen relations of an epiphytic fern. New Phytolog. 180, 5–8.
Wright, J.P., Jones, C.G., 2006. The concept of organisms as ecosystem engineers ten years on: progress, limitations, and challenges. BioScience 56, 203–209.