

BIODIVERSITY

Southernmost records of Entomophthoromycotina. Updated review of Entomophthoralean fungal insect pathogens of Argentina

Registros más australes de Entomophthoromycotina. Revisión de los hongos Entomophthorales patógenos de insectos de la Argentina

Claudia C. López-L^{1*} | Andrea V. Toledo² | Romina G. Manfrino¹ | Alejandra C. Gutierrez¹

- Received: 11/aug/2018
- Accepted: 19/mar/2019
- Published online: 7/may/2019

Citation: López-L CC, Toledo AV, Manfrino RG, Gutierrez AC. 2019. Southernmost records of Entomophthoromycotina. Updated review of Entomophthoralean fungal insect pathogens of Argentina. *Caldasia* 41(2):349–357.
doi: <https://dx.doi.org/10.15446/caldasia.v41n2.72653>.

ABSTRACT

The objective of this work is to further update the records of Argentinean Entomophthoralean fungal species and their geographical distribution. Our survey includes five new records of *Zoophthora radicans* infecting insect hosts belonging to the orders Diptera, Hemiptera, and Lepidoptera from Pampasic and Littoral regions of Argentina. These new records not only increase the host range of Entomophthoralean fungi but also their geographical distribution around the world.

Keywords. Diptera, entomopathogenic fungi, Hemiptera, Lepidoptera, South America

RESUMEN

El objetivo del presente trabajo es actualizar el conocimiento de especies de hongos Entomophthorales de la Argentina y su distribución geográfica. Como resultado incluimos cinco nuevos registros de *Zoophthora radicans* infectando insectos de los órdenes Diptera, Hemiptera y Lepidoptera de las regiones pampásica y litoral de la Argentina. Estas nuevas citas no solo incrementan el espectro hospedador de los hongos Entomophthorales sino también su distribución geográfica a nivel mundial.

Palabras clave. Diptera, Hemiptera, hongos entomopatógenicos, Lepidoptera, Suramérica

¹ Centro de Estudios Parasitológicos y de Vectores CEPAVE (CONICET-UNLP). Calle 61 s/n entre 121 y 122, 1900, La Plata, Buenos Aires, Argentina. claudia@cepave.edu.ar*, manfrino@cepave.edu.ar, gutialeja@gmail.com

² Centro de Investigaciones de Fitopatología (CIDEFI-CICBA), Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata, Avda. 60 y 119 s/n, 1900, La Plata, Buenos Aires, Argentina. E-mail: andytoledo75@yahoo.com.ar

* Autor para correspondencia



INTRODUCTION

Entomophthoromycota (Phylum Zoopagomycota) is a fungal subphylum, which includes a great diversity of species that predominantly infects insects. The previous reports and articles on the subject recorded for Argentina were focused on taxonomy, biodiversity, epizootiology and some laboratory evaluations of biological activity of species *Batkoa* sp., *Conidiobolus coronatus* (Costantin) A. Batko, *C. obscurus* (I.M. Hall & P.H. Dunn) Remaud. & S. Keller, *Entomophaga grylli* (Fresenius) Batko, *E. planchoniana* Cornu, *E. ferdinandii* S. Keller, *Neozygites* sp., *N. fresenii* (Nowak.) Remaud. & S. Keller, *Pandora* sp., *P. dipterigena* (Thaxt.) Humber, *P. gammae* (Weiser) Humber, *P. neoaphidis* (Remaud. & Hennebert) Humber, *P. nouryi* (Remaud. & Hennebert) Humber, *Zoophthora* sp. and *Z. radicans* (Bref.) A. Batko.

Entomophthoralean fungi infecting insects have been studied and reported from all over the world (Eilenberg et al. 1987, Keller 1987, Feng et al. 1990, Eilenberg et al. 1992, Balazy 1993, Santamaría and Girbal 1996, Hatting et al. 1999, Nielsen et al. 2001, Pell et al. 2001, Steinkraus and Boys 2005, Jensen et al. 2009, Hajek et al. 2012, Humber 2012), while this fungal group was poorly studied in South America (Aruta et al. 1974, 1984, Delalibera et al. 1992, Alzugaray et al. 1999). The first Argentinean reference was published by Fresa (1979) but in the last decade, the number of publications about this fungal group has increased (Méndez-Sánchez et al. 2001, 2002a, b, 2009, Delalibera et al. 2004, López-L and Scorsetti 2007, Scorsetti and López-L 2007, Toledo et al. 2007, 2008a, b, Jensen et al. 2009, Alzugaray et al. 2010, Scorsetti et al. 2010, 2012, Sosa Gómez et al. 2010, Manfrino et al. 2013, 2014a, b, c, Montalva et al. 2016a, b). The overall goal of this work is to follow this endeavor and further update the knowledge of Argentinean Entomophthoralean fungal species with new records that expanded their insect host range and their geographical distribution.

MATERIALS AND METHODS

Survey of Entomophthoralean fungi were performed collecting dead and alive insects in different types of environments as poultry houses (houseflies), crops (Lepidoptera and Hemiptera) and natural preserved areas (Diptera). Insects infected with Entomophthoralean fungi were collected from under plant leaves, walls, and leaf litter in several localities from Argentina (Fig. 1) during 2004–2014.

Fungal infected insects were used for actively discharging conidia in a typical “descendent discharge” according to the methodology described by Eilenberg et al. (1992), Keller (2006, 2007). Conidia were cultured on Sabouraud dextrose agar with yeast extract + egg yolk + skimmed milk (Hajek et al. 2012) and incubated at 20 °C in darkness. Fungal structures were stained with aceto-orcein 1 %. Observations were performed by using an Optic Microscope Olympus CH30 and photographs with a differential interference contrast fitted with a Power Shot A80 camera. The taxonomic identification was based on the morphology of conidiophores, morphology, and sizes of conidia, rhizoids and cystidia and presence or absence of resting spores, using the keys and monographs of Balazy (1993), Keller (2007) and Humber (2012).

RESULTS

Entomophthoralean species recorded up to date in Argentina are listed below. This information includes a brief description of the five new records of *Zoophthora radicans* (Bref.) Batko, infecting insect hosts belonging to the orders Diptera, Hemiptera, and Lepidoptera. These new records, marked with an asterisk in the checklist, not only increase the host range of Entomophthoralean fungi but also their geographical distribution.

As a result of this study, it was possible to obtain and preserved three fungal isolates of *Z. radicans*, which were deposited in the Agricultural Research Service Entomopathogenic Fungi collection (ARSEF) (Ithaca, New York, USA) under the accession numbers ARSEF 5814, ARSEF 6917 and ARSEF 8466. The other records reported as new in this study are kept as reference dried material (*exicata*) or as permanent microscopic slides (mounted in LPAO Lactophenol-aceto-orcein and sealed with nail polish) at CEPAVE Fungarium Collection (Centro de Estudios Parasitológicos y de Vectores) (La Plata, Buenos Aires, Argentina).

Entomophthoraceae

Entomophaga grylli (Fresen.) A. Batko

Synonyms: *Conidiobolus grylli* (Fresen.) Remaud. & S. Keller,
= *Empusa grylli* (Fresen.) Nowak
= *Entomophthora grylli* Fresenius.

Material examined: ARGENTINA. BUENOS AIRES: General Villegas 35°02'00" S, 63° 01'00" W, Villa Saurí 37°7'0.12" S; 62°58'59.87" W and Benito Juárez (37°49'00" S, 57°49'00" W. LA PAMPA: Eduardo Castex 35°54'S; 64°18' W and Santa Rosa 36°37' 13"S, 64°17'26" W.



Figure 1. Distribution of Entomophthoralean sampling sites for Argentina.

Hosts: Orthoptera Acrididae, several species.

References: (Fresa 1971, Lange 1996).

***Entomophthora ferdinandii* S. Keller**

Synonyms: *Entomophthora ferdinandii* S. Keller [as 'ferdinandi']

Material examined: ARGENTINA. BUENOS AIRES: La Plata 34°05'05" S, 58°10'26" W, 23. IX. 2001. C.C. López-L (CEPhe22).

Host: *Musca domestica* L. (Diptera: Muscidae) (Fig. 2a).

References: (López-L et al. 2006, Jensen et al. 2009).

***Entomophthora planchoniana* Cornu**

Synonyms: *Empusa planchoniana* (Cornu) Thaxt.
= *Myiophyton planchonianum* (Cornu) Arx.

Material examined: ARGENTINA. BUENOS AIRES: La Plata, Colonia Urquiza 34°56'19.2" S, 58°6'3.8" W, 1. IV. 2004), SANTA FE: Rafaela and Monte Vera, 31°12'3.67" S, 61°30'25.83" W, 24.VI.2010.

Host: Hemiptera Aphididae, several species (Figs. 2b, c).
A.C. Scorsetti, R.G. Manfrino, C.C. López-L (LPSC 47458).

References: (López-L and Scorsetti 2006, Scorsetti et al. 2007, Jensen et al. 2009, Manfrino et al. 2013, 2014 a, c).

***Pandora gammae* (J. Weiser) Humber**

Synonyms: *Entomophthora gammae* (J. Weiser) D.M. MacLeod & Müll-Kög.

= *Erynia gammae* (J. Weiser) Glare & Milner,

= *Tarichium gammae* J. Weiser

= *Zoopthora gammae* (J. Weiser) Balazy.

Material examined: ARGENTINA. BUENOS AIRES: Chivilcoy, 34°54'00" S, 60°02'00" W 1. IV. 1996, and CORDOBA: Manfredi, 31°49' S, 63°46' W.

Hosts: *Anticarsia gemmatilis* (Hübner) and *Rachiplusia nu* (Guenée) (Lepidoptera: Noctuidae), C.C. López-L. Herbarium material accession number CEP100/ENT98.

References: (Edelstein and Lecuona 2003, López-L and Scorsetti 2006).

***P. neoaphidis* (Remaud. & Hennebert) Humber**

Synonyms: *Erynia neoaphidis* Remaud. & Hennebert,
= *Zoophtora neoaphidis* (Remaud. & Hennebert)
Balazy,
= *Zoophtora neoaphidis* (Remaud. & Hennebert)
Ben Ze'ev & R.G. Kenneth.

Material examined: ARGENTINA. BUENOS AIRES: La Plata, Colonia Urquiza, 34°56'19.2" S, 58°6'3.8" W, SANTA FE: Monte Vera, 31°32'49"S; 60°41'33"W, 16. X. 2010.

Hosts: Hemiptera Aphididae, several species (Figs. 3a, b).

A.C. Scorsetti, R.G. Manfrino (LPSC 47466, LPSC47459, LPSC 47460)

References: (Scorsetti et al. 2007, 2012, Manfrino et al. 2013, 2014a, b, c)

***P. nouri* (Remaud. & Hennebert) Humber**

Synonyms: *Erynia nouri* Remaud. & Hennebert,
= *Zoophtora nouri* (Remaud. & Hennebert)
Ben Ze'ev & R.G. Kenneth.

Material examined: ARGENTINA. BUENOS AIRES: La Plata, 34°55'49" S, 57°56'32" W, 28.VIII. 2005.

Host: *Heterocaecilius* sp. (Psocodea: Pseudocaeciliidae) (Figs. 3c, d) A.V. Toledo (LPSC 47784).

Reference: (Toledo et al. 2008b).

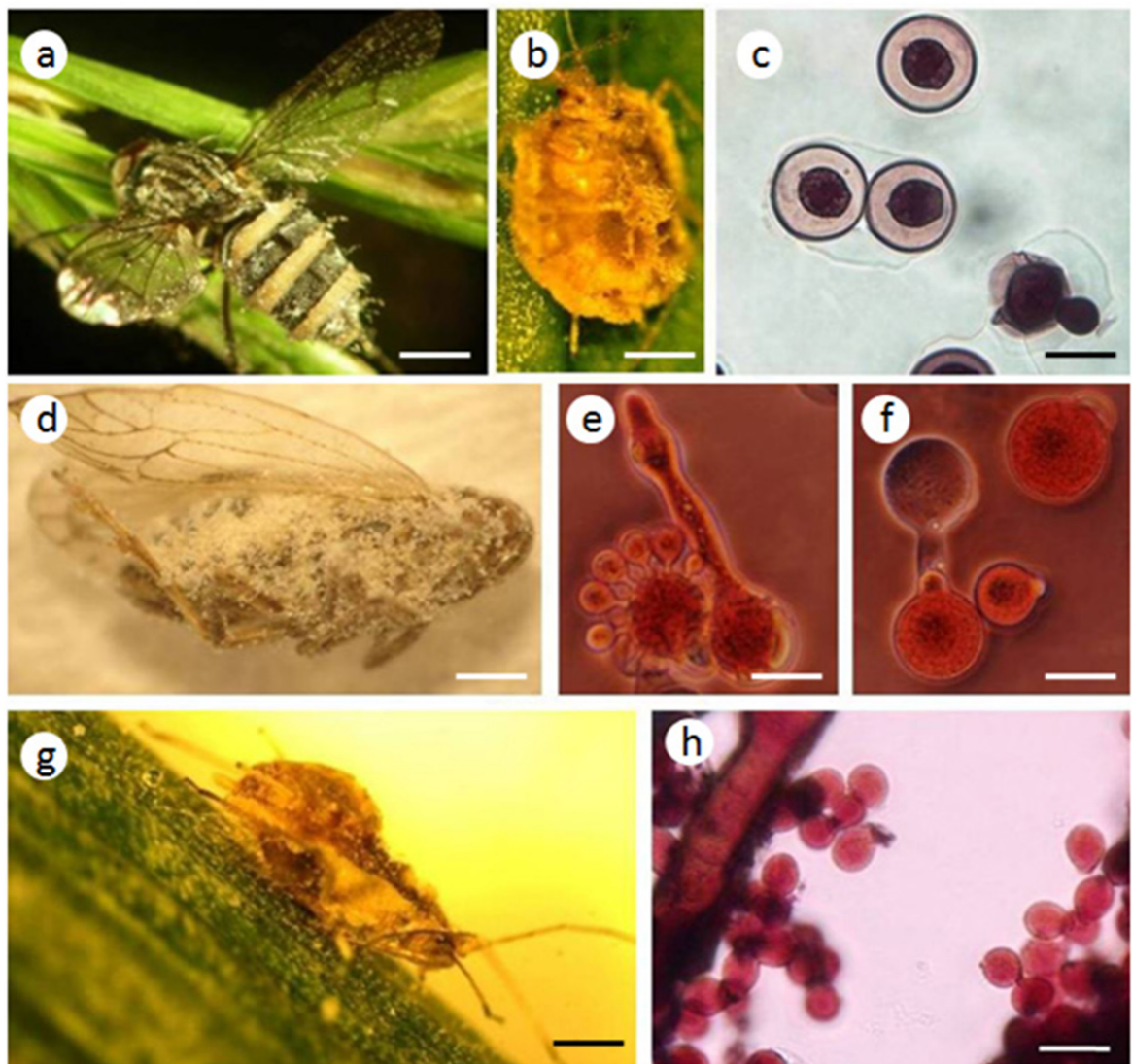


Figure 2. Insect hosts infected with Entomophthoralean fungi species and conidia. **a.** *Musca domestica* infected with *Entomophthora ferdinandii*; **b.** *Myzus persicae* infected with *E. planchoniana*; **c.** Primary conidia of *E. planchoniana*; **d.** *Delphacodes kuscheli* infected with *Conidiobolus coronatus*; **e.** Microconidia of *C. coronatus* isolated from *Ollarius dimidiatus*; **f.** Primary and secondary conidia of *C. coronatus* isolated from *O. dimidiatus*; **g.** *Schizaphis graminum* infected with *Neozygites fresenii*; **h.** Primary conidia of *N. fresenii*. Scale bars: a = 1.3 mm, b = 0.6 mm, c = 20 µm, d = 0.5 mm, e = 33.5 µm, f = 29 µm, g = 2.5 mm, h = 28.3 µm.

Zoophthora radicans (Bref.) A. Batko

Synonyms: *Empusa radicans* Brefeld.

Material examined: ARGENTINA. BUENOS AIRES: La Plata, Arana 35°0'19.8" S, 57° 55'30" W and Colonia Urquiza 34°56'19.2" S, 58°6'3.8" W, Berazategui, Parque Pereyra Iraola 34°50'36.5" S, 58°33.2" W and Magdalena, General Mansilla 35°5' 30.7" S, 57°45'20.6" W. SANTA FE: Monte Vera 31°32'58.21" S, 60°41'34.74" W, Rafaela 31°12'3.67" S, 61° 30' 25.83" W, Sarmiento 31°3'24.84" S, 61°10'13.29" W and Ceres 29°52'55.38"S, 61°56'25" W, 1.VI.2010.

Hosts: Hemiptera Aphididae, several species (Figs. 3e, f). Culture collection accession numbers ARSEF 7208, ARSEF 7455, ARSEF 7788, ARSEF 7789. A.C. Scorsetti, R.G. Manfrino, (LPSC 47467, LPSC 47460).

References: (Scorsetti et al. 2007, Manfrino et al. 2013, 2014a, b, c)

*** Z. radicans**

New record. Material examined: ARGENTINA. CORRIENTES: Las Marías (28°6'44" S, 56°3'5" W, 1. IX. 2009. S. Durman, C.C. López-L. (CEPhe42)

Description. Microscopic characters: Primary conidia clavate and uninucleate: $17.2 (\pm 0.5) \times 5.8 (\pm 0.4) \mu\text{m}$. Secondary conidia: $9.2 (\pm 0.5) \times 5.1 (\pm 0.2) \mu\text{m}$. Capilliconidia: $8.2 (\pm 1.2) \times 2.2 (\pm 0.2) \mu\text{m}$. Rhizoids and resting spores were not observed.

Host: Adults of *Gyropsilla spegazziniana* (Lizer & Trelles) (Hemiptera: Psyllidae) collected from *Ilex paraguariensis* (St.-Hil.) (Aquifoliaceae)

*** Z. radicans**

New record. Material examined: ARGENTINA. BUENOS AIRES: La Plata, Colonia Urquiza, 34°55' 43"S, 58°1' 48" W, 5. VI. 2001 C.C. López-L, C.C. (ARSEF 6917).

Description. Microscopic characters: Primary conidia clavate and uninucleate: $16.5 (\pm 0.6) \times 6.3 (\pm 0.3) \mu\text{m}$. Secondary conidia: $9.7 (\pm 0.5) \times 4.2 (\pm 0.32) \mu\text{m}$. Capilliconidia: $7.7 (\pm 1.3) \times 2.37 \mu\text{m}$.

Host: Larva of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) collected from *Solanum lycopersicum* L. (Solanaceae) in covered greenhouses.

*** Z. radicans**

New record. Material examined: ARGENTINA. BUENOS AIRES: La Plata, 34°55'30" S, 57°56'38" W, 5. V. 2007. A.V. Toledo, (ARSEF 8466).

Description. Microscopic characters: Conidiophores digitately branched. Primary conidia clavate and uninucleate with basal papilla rounded: 14.9 ± 0.2 (12–16.8) μm in length $\times$ 5.6 ± 0.1 (4.8–7.2) μm in width. No rhizoids, cystidia or resistance spores were observed.

Host: Females of unidentified species of Diptera Chironomidae collected from walls. (Figs. 3g, i).

*** Z. radicans**

New record. Material examined: ARGENTINA. SANTA FÉ: Monte Vera 31°32'58" S, 60°41'34" W, 13.V. 2011. R.G. Manfrino (CEPhe50).

Description. Microscopic characters: Conidia uninucleate, primary conidia elongate, papilla generally conical demarcated with a slight protuberance from the body of the conidia: 20.2 ± 2.3 (15.7–24.0) in length $\times$ 6.2 ± 0.8 (4.9–7.4) μm in width. Secondary conidia as capilliconidia: 20.0 ± 1.8 (18.9–24.4) $\times$ 7.1 ± 0.5 (6.4–7.9) $\times$ 46.9 ± 9.7 (35.8–60.3) μm . Thin rhizoids compound with specialized adhesive disc. No resistance spores were observed.

Host: Larvae of *Plutella xylostella* L. (Lepidoptera: Plutellidae) collected from *Brassica oleracea* var. *capitata* L. (Brassicaceae).

*** Z. radicans**

New record. Material examined: ARGENTINA. BUENOS AIRES: Los Hornos, 34°59'8" S, 57°59'53" W, 28.V. 1998. López-L. C.C. (ARSEF 5814).

Description. Microscopic characters: Primary conidia clavate and uninucleate: $15.5\text{--}22.5 \times 6.3\text{--}8.4 \mu\text{m}$. Secondary conidia as capilliconidia $17.3\text{--}21.8 (\pm 0.5) \times 4.6\text{--}5.9 (\pm 1.2) \mu\text{m}$. Resting spores not observed.

Host: Larva of *Epinotia aporema* (Walsingham) (Lepidoptera: Tortricidae) collected from *Lupinus* sp. (Fabaceae).

Ancylistaceae**Conidiobolus coronatus (Costantin) A. Batko**

Synonyms: *Boudierella coronata* Costantin

= *Conidiobolus villosus* G.W. Martin

= *Delacroixia coronata* (Costantin) Sacc. & P. Syd.

= *Entomophthora coronata* (Costantin) Kevorkian.

Material examined: ARGENTINA. BUENOS AIRES: La Plata 35°54'18" S, 57°57'0.3" W and Los Hornos 34°52'S, 57°58' W. 19. VIIII. 2003. A.V. Toledo (LPSC 47779)

Hosts: *Delphacodes kuscheli* (Fennah), *D. haywardi* Muir (Hemiptera: Delphacidae) and *Oliarus dimidiatus* Berg (Hemiptera: Cixiidae) (Figs. 2a, c).

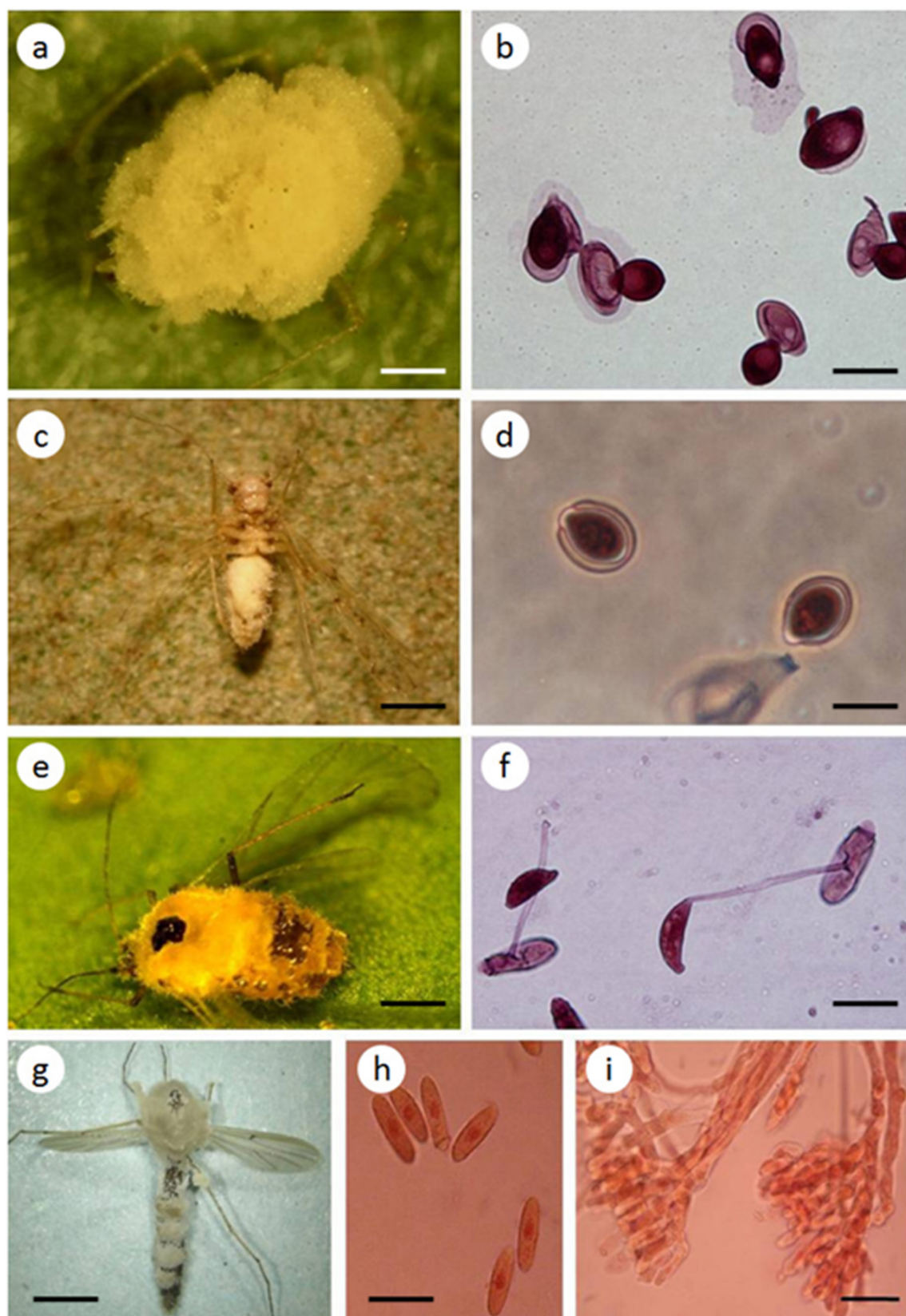


Figure 3. Different type of conidia of Entomophthoralean fungal species. **a.** *Myzus persicae* infected with *Pandora neoaphidis*; **b.** Bitunicate primary conidia of *P. neoaphidis*; **c.** *Heteroecilius* sp. infected with *P. noursy*; **d.** Bitunicate primary conidia of *P. noursy*; **e.** *Brevicoryne brassicae* infected with *Zoophthora radicans*; **f.** Capilliconidia of *Z. radicans*; **g.** Unidentified species (Diptera: Chironomidae) infected with *Z. radicans*; **h.** *Z. radicans* primary conidia, and **i** conidiophores. Scale bars: a = 0.4 mm, b = 28 μ m, c = 0.3 mm, d = 12.3 μ m, e = 0.5 mm, f = 15.3 μ m, g = 2 mm, h = 23 μ m, i = 12.5 μ m.

Culture collection accession number ARSEF 7203.

References: (Toledo *et al.* 2007, 2008a).

C. obscurus (I.M. Hall & P.H. Dunn) Remaud. & S. Keller

Synonyms: *Empusa thaxteriana* Petch,

= *Entomophaga obscura* (I.M. Hall & P.H. Dunn)

A. Batko,

= *Entomophaga thaxteriana* A. Batko,

= *Entomophthora ignobilis* I.M. Hall & P.H. Dunn,

= *Entomophthora obscura* I.M. Hall & P.H. Dunn,

= *Entomophthora thaxteriana* I.M. Hall & J. Bell,

= *Entomophthora thaxteriana* Petr.

Material examined: ARGENTINA. BUENOS AIRES: Bera-zategui, Parque Pereyra Iraola 34°50'36.5" S, 58°5'33.2" W, La Plata, Colonia Urquiza 34°56'19.2" S, 58°6'3.8" W and Los Cardales 34°19'25.2" S, 58°59'41.4" W 1. XI. 2002. A.C. Scorsetti (LPSC 47461).

Hosts: *Neotoxoptera formosana* (Takahashi), *Nasonovia ribisnigri* (Mosley), *Brevicoryne brassicae* L. and *Myzus* sp. (Hemiptera: Aphididae).

References: (Scorsetti *et al.* 2007, Comerio *et al.* 2008)

Neozygitaceae

***Neozygites fresenii* (Nowak.) Remaud. & S. Keller**

Synonyms: *Empusa fresenii* Nowak.

= *Entomophthora fresenii* (Nowak.) M.A. Gust.

= *Entomophthora neri* M.A. Gust.

= *Neozygites aphidis* Witlaczil,

= *Triplosporium fresenii* (Nowak.) A. Batko.

Material examined: ARGENTINA. SANTA FE: Monte Vera 31°32'58.21" S, 60°41'34.74" W and Rafaela (31°12'6.62" S, 61°30'11.14" W, 3. III.2011.

Hosts: Hemiptera Aphididae, several species (Figs. 2g, h). R.G. Manfrino (LPSC 47468).

References: (Manfrino *et al.* 2014a, b).

DISCUSSION

Knowledge about distribution and diversity of Entomophthoralean species infecting arthropods in Argentina is scarce and spread out.

As result of our study, the insect host range of these fungi was extended, being Hemiptera the order with the highest number of species infected with Entomophthoralean fungi, and followed by Lepidoptera and Diptera species, even though there are a lot of other insect groups that up to date there were never surveyed in order to look for Entomophthoralean fungi in Argentina yet.

Molecular taxonomic identification and characterization of fungal species are being to be submitted for publication soon, and these studies will contribute to reinforce and strongly support the present records (Manfrino, com. Pers.). We hope that as a result of future researches the number of species recorded in Argentina will increase in accordance with the diversity of habitats that owns the country.

AUTHOR'S CONTRIBUTION

RM and AT collected the samples; CL identified the specimens; CL and AT wrote the text. AG made the map and figures.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

ACKNOWLEDGMENTS

This work was partially financed by CONICET (National Research Council of Argentina) and FCNyM- UNLP (Natural Sciences College University of La Plata). We thanks to Rich Humber of ARSEF Culture Collection, for preserving specific cultures and confirmed some species identification, and to Ms. M.L. Morote for collaborating with illustrations.

LITERATURE CITED

- Alzugaray R, Zerbino MS, Stewart S, Ribeiro A, Eilenberg J. 1999. Epizootiología de hongos Entomophthorales. Uso de *Zoophthora radicans* (Brefeld) Batko (Zygomycotina: Entomophthorales) para el control de *Epinotia aporema* (Wals.) (Lepidoptera: Tortricidae) en Uruguay. Rev. Soc. Entomol. Argent. 58(1-2):307-311.
- Alzugaray R, Ribeiro A, Silva H, Stewart S, Castiglioni E, Bartaburu S, Martínez JJ. 2010. Prospección de agentes de mortalidad natural de áfidos en leguminosas forrajeras en Uruguay. Agrociencia 14(1):27-35.
- Aruta C, Carrillo R, González S. 1974. Determinación para Chile de hongos entomopatógenos del género *Entomophthora* I. Agro Sur 2(2):62-70.
- Aruta C, Carrillo R, Montealegre J. 1984 Determinación para Chile del Orden Entomophthorales (Zygomycetes). Agro Sur 12(1):36-42.
- Bałazy S. 1993. Entomophthorales, Flora of Poland (Flora Polska), Fungi (Mycota). 24: Krakow, Polish Academy of Science, W. Szafer Institute of Botany.
- Comerio RM, Andorno AV, Botto EN. 2008 Aislamiento de *Conidiobolus coronatus* a partir de una plaga de áfidos del cebollín (*Allium schoenoprasum* L.). Rev. Iberoam. Micol. 25(3):193-195. doi: [https://dx.doi.org/10.1016/S1130-1406\(08\)70046-9](https://dx.doi.org/10.1016/S1130-1406(08)70046-9).
- Delalibera Jr. I, Sosa Gómez DR, De Moraes GJ, De Alencar JA, Araujo W. 1992. Infection of *Mononychellus tanajoa* (Acari: Tetranychidae) by the fungus *Neozygites* sp. (Entomophthorales) in Northeastern Brazil. Fla. Entomol. 75(1):145-147. doi: <https://dx.doi.org/10.2307/3495493>.
- Delalibera Jr I, Hajek AE, Humber RA. 2004. *Neozygites tanajoae* sp. nov, a pathogen of the cassava green mite. Mycologia 96(5):1002-1009. doi: <https://dx.doi.org/10.1080/15572536.2005.11832900>.
- Edelstein JD, Lecuona RE. 2003. Presencia del hongo entomopatógeno *Pandora gammae* (Weiser) Humber (Zygomycetes: Entomophthorales) en el complejo de orugas medidoras de la soja (Lepidoptera: Plusiinae) en Argentina. Rev. Investig. Agropecu. 32(1):31-38.
- Eilenberg J, Bresciani J, Martin J. 1987. *Entomophthora* species with *E. muscae*-like spores on two new insect host orders, Coleoptera and Hymenoptera. Nord. J. Bot. 7(5):577-584. doi: <https://dx.doi.org/10.1111/j.1756-1051.1987.tb02026.x>.
- Eilenberg J, Wilding N, Bresciani J. 1992. Isolation *in vitro* of *Strongwellsea castrans* (Fungi: Entomophthorales) a pathogen of adult cabbage root flies, *Delia radicum* (Diptera: Anthomyiidae). Entomophaga 37(1):65-77. doi: <https://dx.doi.org/10.1007/BF02372975>.
- Feng MG, Johnson JB, Kish LP. 1990. Survey of entomopathogenic fungi naturally infecting aphids (Homoptera: Aphididae) of irrigated grain crops in Southwestern Idaho. Environ. Entomol. 19(5):1534-1542. doi: <https://dx.doi.org/10.1093/ee/19.5.1534>.
- Fresa R. 1971. El hongo *Entomophthora grylli* en tucuras. INTA, Rev. Investig. Agropecu. 7(2):83-88.
- Fresa R. 1979. Hongos entomopatógenos observados en larvas de lepidópteros perjudiciales para cultivos de la República Argentina. IDIA. 373-:149-155.
- Hajek AE, Papierok B, Eilenberg J. 2012. Methods for study of the Entomophthorales. In: Lacey L, editor. Manual of Techniques in Invertebrate Pathology. London: Academic Press. p. 285-315.
- Hatting JL, Humber RA, Poprawski TJ, Miller RM. 1999. A survey of fungal pathogens from South Africa with special reference to cereal aphids. Biol. Control 16(1):1-12. doi: <https://dx.doi.org/10.1006/bcon.1999.0731>.
- Humber RA. 2012. Identification of Entomopathogenic Fungi. In: Lacey LA, editor. Manual of Techniques in Invertebrate Pathology. London: Academic Press. p. 151-187.
- Jensen A, Eilenberg J, López-L C. 2009. Differential divergences of obligatory insect-pathogenic *Entomophthora* species from fly and aphid hosts. FEMS Microbiol. Lett. 300(2):180-187. doi: <https://dx.doi.org/10.1111/j.1574-6968.2009.01778.x>.
- Keller S. 1987. Arthropod-pathogenic Entomophthorales of Switzerland I. *Conidiobolus*, *Entomophaga* and *Entomophthora*. Sydowia 40:122-167.
- Keller S. 2006. Species of Entomophthorales attacking aphids with description of two new species. Sydowia 58(1):38-74.
- Keller S. 2007. Arthropod-pathogenic Entomophthorales from Switzerland III. First addition. Sydowia 59:75-113.
- Lange CE. 1996. Melanoplins (Orthoptera: Acrididae) afectados por micosis en la provincia de Buenos Aires, Argentina. Rev. Soc. Entomol. Arg. 55(1-4):107-109.
- López-L CC, Scorsetti AC. 2006. Hongos patógenos de insectos en Argentina (Zygomycetes: Entomophthorales). Rev. Biol. Trop. 54(2):311-315. doi: <https://dx.doi.org/10.15517/RBT.V54I2.13871>.
- López-L CC, Siri A, García JJ, Eilenberg J, Humber RA. 2006. *Entomophthora ferdinandii* (Zygomycetes: Entomophthorales) causing natural infections of *Musca domestica* (Diptera: Muscidae) in Argentina. Mycopathologia 161(4):251-254. doi: <https://dx.doi.org/10.1007/s11046-005-0248-2>.
- López-L CC, Scorsetti AC. 2007. Revisión de los hongos Entomophthorales (Zygomycota: Zygomycetes) patógenos de insectos de la República Argentina. Bol. Soc. Argent. Bot. 42(1-2):33-37.
- Manfrino RG, Zumoffen L, Salto CE, López-L CC. 2013. Potential plant-aphid-fungal associations aiding conservation biological control of cereal aphids in Argentina. Int. J. Pest. Manage. 59(4):314-318. doi: <https://dx.doi.org/10.1080/09670874.2013.869372>.
- Manfrino RG, Zumoffen L, Salto CE, López-L CC. 2014a. Natural occurrence of entomophthoroid fungi of aphids pests on *Medicago sativa* L. in Argentina. Rev. Argent. Microbiol. 46(1): 49-52. doi: [https://dx.doi.org/10.1016/S0325-7541\(14\)70048-3](https://dx.doi.org/10.1016/S0325-7541(14)70048-3).

- Manfrino RG, Hatting JL, Humber RA, Salto CE, López-L CC. 2014b. Natural occurrence of entomophthoroid fungi (Entomophthoromycota) of aphids (Hemiptera: Aphididae) on cereal crops in Argentina. *Ann. Appl. Biol.* 164(1):151–158. doi: <https://dx.doi.org/10.1111/aab.12089>.
- Manfrino RG, Gutierrez AC, Steinkraus D, Salto CE, López-L CC. 2014c. Prevalence of entomophthoralean fungi (Entomophthoromycota) of aphids (Hemiptera: Aphididae) on solanaceous crops in Argentina. *J. Invertebr. Pathol.* 121:21–23. doi: <https://dx.doi.org/10.1016/j.jip.2014.06.003>.
- Méndez-Sánchez SE, Freitas AL, Roberts DW. 2001. Detección de hongos Entomophthorales patógenos a insectos fitófagos, al sur de Bahía, Brasil. *Entomotropical* 16(3):203–206.
- Méndez-Sánchez SE, Freitas AL, Almeida CS, Silva GB, Lima LS. 2002a. Levantamiento preliminar de hongos Entomophthorales (Zygomycotina; Zygomycetes), agentes de control natural de insectos al sur de Bahía, Brasil. *Agrotrópica* 14(2):77–80.
- Méndez-Sánchez SE, Roberts DW, Freitas AL, Lima LS, Silva GB, Almeida de CS, Nunes EF. 2002b. Prospección de hongos Entomophthorales para el control natural de insectos en Bahía, Brasil. *Manejo Integrado de Plagas y Agroecología* 66:20–30.
- Méndez-Sánchez SE, Humber RA, Freitas AL. 2009. El complejo *Entomophaga grylli* (Fresenius 1856) Batko (Zygomycetes: Entomophthorales) infectando saltamontes (Orthoptera: Acrididae) en Ilhéus (Bahía), Brasil: Notas y nuevos registros. *Entomotropical* 24(2):71–81.
- Montalva C, Luz C, Humber RA. 2016a. *Neozygites osornensis* (Neozygites: Neozygiteaceae) infecting *Cinara* sp. (Hemiptera: Aphididae) in Brazil. *Neotrop. Entomol.* 45(2):227–230. doi: <https://dx.doi.org/10.1007/s13744-016-0369-y>.
- Montalva C, Collier K, Luz WC, Humber RA. 2016b. *Pandora bullata* (Entomophthoromycota: Entomophthorales) affecting calliphorid flies in central Brazil. *Acta Trop.* 158:177–180. doi: <https://dx.doi.org/10.1016/j.actatropica.2016.03.007>.
- Nielsen C, Eilenberg J, Harding S, Oddsdottir E, Halldórsson G. 2001. Geographical distribution and host range of Entomophthorales infecting the green spruce aphid *Elatobium abietinum* Walker in Iceland. *J. Invertebr. Pathol.* 78(2):72–80. doi: <https://dx.doi.org/10.1006/jip.2001.5045>.
- Pell JK, Eilenberg J, Hajek AE, Steinkraus DC. 2001. Biology, ecology and pest management potential of Entomophthorales. In: Butt TM, Jackson CW, Magan N, editors. *Fungi as Biocontrol Agents: Progress, Problems and Potential*. Wallingford, England: CABI Publishing. p. 71–153.
- Santamaría S, Girbal J. 1996. Contribución al conocimiento de los Entomophthorales (Zygomycotina) Ibéricos. *Rev. Iberoam. Mic.* 13:37–43.
- Scorsetti AC, Humber RA, García JJ, López-L CC. 2007. Natural occurrence of entomopathogenic fungi (Zygomycetes: Entomophthorales) of aphid (Hemiptera: Aphididae) pests of horticultural crops in Argentina. *BioControl* 52(5):641–655. doi: <https://dx.doi.org/10.1007/s10526-006-9045-1>.
- Scorsetti AC, López-L CC. 2007. Primer registro del hongo *Neozygites* sp. (Zygomycota: Entomophthorales), patógeno de *Tetranychus urticae* (Acari: Tetranychidae) en la República Argentina. *Bol. Soc. Argent. Bot.* 42(3–4):189–193.
- Scorsetti AC, Maciá A, Steinkraus DC, López-L CC. 2010. Prevalence of *Pandora neoaphidis* (Zygomycetes: Entomophthorales) infecting *Nasonovia ribisnigri* (Hemiptera: Aphididae) on lettuce crops in Argentina. *Biol. Control* 52(1):46–50. doi: <https://dx.doi.org/10.1016/j.biocontrol.2009.09.005>.
- Scorsetti AC, Jensen AB, López-L CC, Humber RA. 2012. First report of *Pandora neoaphidis* resting spore formation *in vivo* in aphid hosts. *Fungal. Biol.* 116(2):196–203. doi: <https://dx.doi.org/10.1016/j.funbio.2011.11.002>.
- Sosa-Gómez DR, López-L CC, Humber RA. 2010. An overview of arthropod-associated fungi from Argentina and Brazil. *Mycopathologia* 170(1):61–76. doi: <https://dx.doi.org/10.1007/s11046-010-9288-3>.
- Steinkraus DC, Boys GO. 2005. Mass harvesting of the entomopathogenic fungus, *Neozygites fresenii*, from natural field epizootics in the aphid, *Aphis gossypii*. *J. Invertebr. Pathol.* 88(3):212–217. doi: <https://dx.doi.org/10.1016/j.jip.2005.01.008>.
- Toledo AV, Marino de Remes-L AM, López-L CC. 2007. Primer registro de *Conidiobolus coronatus* (Zygomycetes: Entomophthorales) en crías experimentales de dos especies plaga del maíz: *Delphacodes kuscheli* y *D. haywardi* (Hemiptera: Delphacidae) en la Argentina. *Bol. Soc. Argent. Bot.* 42(3–4):169–174.
- Toledo AV, Giambelluca L, Marino de Remes-L AM, López-L CC. 2008a. Pathogenic fungi of planthoppers associated with rice crops in Argentina. *Int. J. Pest. Manage.* 54(4):363–368. doi: <https://dx.doi.org/10.1080/09670870802266961>.
- Toledo AV, Humber RA, López-L CC. 2008b. First and southernmost records of *Hirsutella* (Ascomycota: Hypocreales) and *Pandora* (Zygomycota: Entomophthorales) species infecting Dermaptera and Psocodea. *J. Invertebr. Pathol.* 97(2):193–196. doi: <https://dx.doi.org/10.1016/j.jip.2007.09.001>.