Acarologia

A quarterly journal of acarology, since 1959
Publishing on all aspects of the Acari

All information:

<http://www1.montpellier.inra.fr/CBGP/acarologia/>
acarologia-contact@supagro.fr

**Acarologia is proudly non-profit,
with no page charges and free open access**

Please help us maintain this system by
encouraging your institutes to subscribe to the print version of the journal
and by sending us your high quality research on the Acari.

Subscriptions: Year 2023 (Volume 63): 450 €

<http://www1.montpellier.inra.fr/CBGP/acarologia/subscribe.php>

Previous volumes (2010-2021): 250 € / year (4 issues)

Acarologia, CBGP, CS 30016, 34988 MONTFERRIER-sur-LEZ Cedex, France

ISSN 0044-586X (print), ISSN 2107-7207 (electronic)

The digitalization of Acarologia papers prior to 2000 was supported by Agropolis Fondation under the reference ID 1500-024 through the « Investissements d'avenir » programme (Labex Agro: ANR-10-LABX-0001-01)

Supporting agricultural research
for sustainable development

**Acarologia is under free license and distributed under the terms of the
Creative Commons-BY**

SHORT NOTE

An unexpected occurrence of *Amblyseius swirskii* (Athias-Henriot)
in La Réunion Island (Acari: Phytoseiidae)

Serge KREITER¹, Victor VICENTE¹, Marie-Stéphane TIXIER¹ and Olivier FONTAINE²

(Received 15 April 2016; accepted 25 April 2016; published online 10 May 2016)

¹ Montpellier SupAgro, UMR CBGP INRA/IRD/CIRAD/ Montpellier SupAgro, 755 Avenue du Campus International Agropolis, CS 30016, 34988 Montpellier-sur-Lez cedex, France. serge.kreiter@supagro.fr, victor.vicente@supagro.fr, marie-stephane.tixier@supagro.fr
² SARL La Coccinelle, 6 Chemin Beaurivage, 97410 Saint-Pierre (La Réunion), France. coccinelle.reunion@gmail.com

ABSTRACT — The identity of specimens of phytoseiid mites collected inside greenhouses infested by thrips in La Réunion Island was assessed. As the sampled species belongs to the genus *Amblyseius*, presently containing 415 species which are notoriously difficult to discriminate, morphological and molecular traits were evaluated. Both morphological and DNA comparisons showed that the collected specimens belong to the species *Amblyseius swirskii*, a successful biological control agent introduced in the market more than ten years ago in Europe and Northern America. This finding was unexpected, as this species was never reported in this part of the world; an accidental introduction is thus suspected.

KEYWORDS — thrips, pepper, roses, biological control agent, 12S rRNA

INTRODUCTION

Biological control is the most environmentally safe and most economical mode of pest management for growers (Cock *et al.* 2010). Augmentative biological control has been proved to be an efficient alternative to chemical control in vegetable production in greenhouses (van Lenteren and Bueno 2003). The biocontrol industry has made great advances in the last decades with the discovery of more than 230 species of natural enemies available for augmentative biological control worldwide (van Lenteren 2012). Among them, phytoseiid mites are efficient

predators of small insects and mites (McMurtry *et al.* 2013). They are considered important biocontrol agents with many species sold and used all around the world (Wright 2004). The predatory mite *Amblyseius swirskii* Athias-Henriot, 1962 (Acari: Phytoseiidae) is one of the most efficient; it is currently released in more than 50 countries of the world. It originates from the East Mediterranean coast and has been described in 1962 from almond (*Prunus amygdalus* [Miller] D.A. Webb) in Bet Dagan, Israel by Athias-Henriot (1962). This species was then reported along the coast of Israel, Middle Eastern countries, Southern Europe, Sub-Saharan Africa

and the America (Demite *et al.* 2016).

Three species have been recently established as junior synonyms of *A. swirskii*:

- *Amblyseius capsicum* (Basha, Youssef, Ibrahim & Mostafa, 2001), described and reported from Egypt on *Capsicum annuum* L. (Solanaceae) (Demite *et al.* 2016).
- *Amblyseius enab* El-Badry 1967, described and reported from Egypt on *Mangifera indica* L. (Anacardiaceae) (Demite *et al.* 2016).
- *Amblyseius rykei* Pritchard & Baker 1962, described from Congo on *Hoslundia opposita* Vahl (Lamiaceae) and reported in Benin, Cuba, Congo, Ghana, Kenya, Malawi, Nigeria and Zimbabwe (Demite *et al.* 2016).

Thus, this species is able to develop not only in the Mediterranean basin but also in subtropical and tropical areas (Zannou and Hanna 2011). Since this species is not entering diapause, it can be used throughout much of the season where daytime temperatures regularly exceed 22 °C (Calvo *et al.* 2015). *Amblyseius swirskii* is commonly used to control whiteflies and thrips in greenhouse vegetables (especially cucumber, pepper and eggplant) and some ornamental crops, in Europe and North America (Calvo *et al.* 2015). The biology of this species and its importance for biocontrol were recently reviewed by Calvo *et al.* (2015) and Buitenhuis *et al.* (2015).

In 2015, a species looking like *A. swirskii* was discovered after a thrips outbreak on peppers and roses at the Réunion Island, at several thousand kilometres from its supposed native area. *Amblyseius swirskii* was furthermore not reported in previous mite biodiversity surveys in La Réunion Island (Quilici *et al.* 1997, 2000; Kreiter *et al.* 2002; Kreiter *et al.* unp. data). Production of vegetables and ornamentals in greenhouses in this Island correspond to great economic inputs. Furthermore because of recurrent problems with pesticide use (efficiency, environmental and health risks), the development of biological control is very important to improve.

According to the new French regulations on importation of macro-organisms (Anonymous, 2012), *A. swirskii* is currently authorized for sale in the French Metropolitan Area but La Réunion is an

over-seas territory; therefore it is impossible to sell and use this species in this latter area, as it is not indigenous. An importation permit could be requested, but it is expensive and chances to obtain are low. The objective of this paper is thus to assess the identity of the species occurring in the landscape of La Réunion Island in order to determine if the interesting biological control agent *A. swirskii* is occurring in this territory. Furthermore, as the genus *Amblyseius* contains approximately 415 species, as no over-all identification key of species of this genus exists, as many species are morphologically very close (with suspicion of synonymies or cryptic species), both morphological and molecular approaches have been carried to ascertain the diagnosis.

MATERIALS AND METHODS

Collection of mites and mountings

The specimens were collected on pepper plants *Capsicum annuum* L. and on roses *Rosa* sp. inside greenhouses in La Réunion Island in two locations: Bassin-Martin (in city of Saint-Pierre territory), Station Armefflor (lat. 55°31'9" S, long. 21°20'0" E, altitude 450 m) in greenhouse 1 on roses, 13 V 2015 (coll. Olivier Fontaine); Montvert-les-Bas, EARL Le Montvert (lat. 55°32'19" S, long. 21°19'42" E, altitude 582 m), in greenhouse with peppers, 15 V 2015 (coll. Mrs Solène Callarec and Olivier Fontaine); same location, in another greenhouse with peppers, 15 V 2015 (coll. Ingrid Avril) (Table 1). Phytoseiid mites were stored in 95 % ethanol. Part of this material was used for morphological identification; permanent slides were prepared using Hoyer's medium and kept on a hot plate (50 °C) for two weeks. The other part of the material was used for molecular analyses (see below).

Morphological analyses

The concept of generic classification of Chant & McMurtry (2007) is used in this paper. The terminologies for chaetotaxy are those proposed by Lindquist & Evans (1965) as adapted by Rowell *et al.* (1978) for dorsal idiosomal setae and by Chant

TABLE 1: Origin and characteristics of studied populations with molecular sequencing and Genbank accession numbers.

Origin	Locality	GPS Coordinates	Altitude	Host plants	Genbank accession numbers
Koppert BV, Commercial strain of <i>Amblyseius swirskii</i>				Rearings	KX064691
					KX064692
					KX064693
					KX064694
					KX064695
					KX064696
France La Réunion Island Wild strain of <i>Amblyseius</i> sp.	Montvert	55°32'19"S 21°19'42"E	582 m	<i>Capsicum annuum</i>	KX064698
					KX064699
					KX064700
					KX064701
	Bassin-Martin	55°31'9"S 21°20'0"E	450 m	<i>Rosa</i> sp.	KX064702
					KX064703
					KX064697
					KX064704

& Yoshida-Shaul (1991) for ventral idiosomal setae. Adenotaxy and poroidotaxy terminologies are those proposed by Athias-Henriot (1975). Measurements were performed using a phase and interference contrast microscope (Leica DLMB, Leica Microsystems SAS, Rueil-Malmaison, France) (400x magnification). All measurements are given in micrometers (μm). Measurements of specimens collected in La Réunion were compared to measurements of the original description and to measurements of several re-descriptions: specimens from Israel (Porath and Swirski 1965), from several countries in Africa (Zannou *et al.* 2007), Cape Verde (Ueckermann 1992), Egypt (Abo-Shnaf and Moraes 2014), and from Spain (Ferragut *et al.* 2010). All voucher specimens are deposited in the mite collection of Montpellier SupAgro Acarology Collection, UMR CBGP, Montpellier, France.

Molecular analysis

As individuals identified morphologically were very close to *A. swirskii* with only some very minor morphological differences, as many cryptic species exist among many genera of Phytoseiidae and as it is important to ascertain the identity of the species in the perspective of potential further studies and uses, molecular analyses were conducted to assess the identity of mites collected in La Réunion. Specimens of La Réunion Island were compared to specimens of the commercial strain of *A. swirskii* reared and sold by Koppert BV (Veilingweg 14, 2651 BE

Berkel en Rodenrijs, The Netherlands) (Table 1). DNA was individually extracted from females, using a Qiagen DNeasy tissue kit (Qiagen, Hilden, Germany), according to the DNA extraction protocol described in Kanouh *et al.* (2010). After DNA extraction, females were retrieved from the Qiagen column as described by Tixier *et al.* (2010). A mitochondrial DNA markers (12S rRNA) was used to allow efficient molecular species diagnosis (see e.g. Okassa *et al.*, 2009, 2011; Tixier *et al.* 2011, 2012, 2014). Primers for the amplification of the DNA fragments were as follows: 12S rRNA, 5'-3' TACTATGTTACGACTTAT and 3'-5' AAAGTAGGATTAGATACCC (Jeyaprakash and Hoy 2002).

The PCR reactions were performed in a 25 μL volume, containing 4 μL of mite DNA, 2.5 μL (1mM) of buffer 10X, 1 μL (1.5mM) of MgCl_2 , 0.5 μL (0.05mM for each) dNTPs, 0.175 μL (0.7 mM) of each primer, 0.125 μL (0.625 U) of Taq Qiagen and 16.525 μL of water. Thermal cycling conditions were as follows for the 12S rRNA marker: 95 °C for 1 min, followed by 35 cycles of 94 °C for 30 s, 40 °C for 30 s and 72 °C for 1 min, and final extension phase at 72 °C for 5 min. Electrophoresis was carried out on a 1.5 % agarose gel in 0.5 x TBE buffer during 20 min at 100 V. PCR products were sequenced along both strands with Dynamic ET Terminator Cycle Sequencing kit, and purified ExoSAP-IT (Amersham Biosciences, GE Healthcare Europe GmbH, CS 20529-78457, 24 Avenue de l'Europe, 78457 Velizy-Villacoublay), us-

TABLE 2: Morphological measurements of females and males of various populations of *Amblyseius swirskii* in comparison with the population collected in La Réunion Island (females and males). **In bold**: specimen measurements average
 VAS: ventrianal shield; MD: movable digit of the chelicera; FD: fixed digit of the chelicera; L1: leg 1; L2: leg 2; L3: leg 3; L4: leg 4; Spermatheca l.: spermathecal length; Shaft: spermatodactyl digit; *: St1-St5 distances and not St1-St3; ¹ in Athias-Henriot (1962); ² in Ueckermann (1992); ³ in Zannou *et al.* (2007); ⁴ in Ferragut *et al.* (2010); ⁵ in Abo-Shnaf and Moraes (2014); ⁶ in Porath and Swirski (1965)

Character	Females						Males			
	Israel 1962 ¹	Cape Verde 1992 ²	Africa 2007 ³	Spain 2010 ⁴	Egypt 2014 ⁵	La Réunion 2016	Israel 1965 ⁶	Africa 2007 ³	Egypt 2014 ⁵	La Réunion 2016
Specimens number	-	16 specimens	10 specimens	Unknown	8 specimens	10 specimens	10 specimens	1 specimen	5 specimens	5 specimens
DS l	-	347-408	338 (326-352)	345-370	375 (358-397)	384 (368-400)	255-295	258	275 (254-292)	289 (280-300)
DS w	-	211-246	205 (202-208)	188-202	214 (195-224)	233 (205-245)	-	190	179 (145-203)	180 (167-187)
Peritreme extension	j1	j1	j1	j1	j1	j1	-	j1-j3	j1-j3	j1-j3
Solenostomes	-	-	-	7	6	7	7	?	7	7
j1	29 (25-32)	31-39	29 (24-32)	24-28	30 (25-32)	29 (25-31)	21-26	25	22 (20-24)	24 (23-20)
j3	51 (46-57)	57-69	53 (48-56)	56	55 (52-57)	53 (50-58)	44-49	43	44 (41-47)	44 (41-47)
j4	-	8-9	8	9	10 (9-15)	8 (8-10)	5-8	7	8 (7-11)	8 (8-10)
j5	-	8-9	8	8	9 (8-10)	8	5-8	7	8 (7-8)	8
j6	-	9-11	9 (8-10)	8	10 (9-11)	8 (8-10)	5-8	8	8 (7-9)	8
J2	8 (7-9)	9-11	9 (8-10)	8	9 (8-10)	8	5-8	7	8 (7-9)	8
J5	-	9-11	7 (6-8)	8	10 (8-10)	10 (8-10)	5-8	8	8 (7-8)	8
z2	15 (13-20)	12-15	12 (11-16)	16	14 (11-16)	15 (13-15)	12-16	13	14 (12-16)	15 (14-15)
z4	17 (15-26)	12-15	13 (10-16)	16-22	15 (12-18)	15 (15-17)	13-18	13	13 (10-15)	15 (14-15)
z5	-	8-9	7 (6-8)	8-10	8 (7-10)	8 (5-8)	5-8	6	7 (7-8)	8
Z1	-	9-11	9 (8-10)	8-10	11 (10-12)	10 (8-10)	10-16	8	11 (10-13)	8
Z4	72 (67-76)	69-77	73 (69-78)	76-80	73 (70-76)	76 (73-80)	49-62	52	52 (49-53)	58 (55-60)
Z5	108 (102-116)	100-126	110 (106-115)	110-118	109 (105-112)	113 (108-114)	73-81	80	74 (70-78)	79 (78-80)
s4	76 (70-81)	74-85	75 (70-82)	76-80	78 (72-81)	83 (78-100)	57-65	59	61 (57-64)	63 (60-65)
S2	19 (17-25)	15-20	13 (11-14)	16-22	19 (18-21)	18 (17-22)	13-18	14	15 (13-18)	15 (13-18)
S4	12 (10-14)	9-11	9 (8-10)	12-14	11 (8-13)	11 (10-12)	9-13	9	9 (7-13)	14 (13-18)
S5	-	9-11	7 (6-8)	10-12	11 (9-12)	10 (10-11)	9-13	9	9 (8-10)	10 (8-11)
r3	-	23	20 (19-21)	22-25	25 (23-27)	24 (23-25)	21-23	20	21 (19-23)	21 (19-23)
R1	-	12-15	11 (10-13)	14-16	15 (12-17)	15 (13-17)	16-18	14	14 (13-14)	13 (13-15)
Sge I	33 (29-36)	26-31	24	-	29 (27-30)	25	-	-	24 (21-25)	20
Sge II	32 (26-37)	31-39	28 (27-29)	-	33 (32-35)	33 (30-38)	-	25	26 (23-28)	29 (28-30)
Sge III	37 (36-39)	31-39	32	-	36 (35-37)	37 (33-48)	-	24	26 (23-28)	30
Sti III	-	26-28	22 (21-24)	-	27 (26-28)	26 (25-28)	-	20	21 (18-23)	28
Sge IV	64 (61-66)	57-69	61 (56-66)	65	63 (60-65)	64 (60-67)	39-52	39	45 (40-47)	47 (45-48)
Sti IV	45 (42-47)	46-54	44 (40-51)	40-42	47 (44-50)	43 (40-45)	31-44	35	36 (32-38)	38 (35-40)
St IV	62 (53-68)	57-69	59 (53-64)	62-66	66 (60-68)	64 (63-65)	49-62	50	54 (48-58)	54 (50-55)
JV5	-	62-77	-	-	72 (65-72)	67 (63-70)	31-41	-	36 (33-39)	29 (28-31)
L1 length	-	-	-	-	-	377 (362-387)	-	-	-	302 (295-315)
L2 length	-	-	-	-	-	289 (274-320)	-	-	-	239 (225-242)
L3 length	-	-	-	-	-	300 (260-332)	-	-	-	252 (225-250)
L4 length	-	-	-	-	-	402 (382-450)	-	-	-	317 (300-317)
St1-St1	61 (61-62)	-	-	-	63 (55-68)	61 (58-65)	-	-	55 (52-60)	52 (50-53)
St2-St2	-	-	70 (69-70)	-	77 (71-87)	71 (63-78)	-	-	59 (56-63)	60
St3-St3	81 (78-83)	-	-	-	87 (79-91)	85 (82-90)	-	-	61 (56-66)	60 (57-63)
St1-St3	64 (61-66)	-	62	-	-	64 (63-65)	-	-	-	112* (110-113)
St4-St4	-	-	-	-	91 (82-101)	86 (80-92)	-	-	47 (43-51)	49 (48-50)
St5-St5	70 (64-76)	-	73 (67-78)	-	76 (70-81)	68 (60-73)	-	-	39 (35-43)	39 (35-40)
length of VAS	117 (106-129)	130	115 (110-120)	123-134	132 (126-135)	131 (125-140)	112-125	113	121 (109-128)	110 (108-110)
width VAS (ZV2)	83 (78-85)	85-90	79 (72-86)	89-92	83 (71-89)	87 (85-90)	-	145	151 (123-164)	158 (150-160)
width VAS (Anus)	-	-	79 (78-80)	-	86	84 (83-85)	-	-	-	79 (75-80)
Spermatheca l./Shaft	-	-	10	-	11	10	-	19	20 (19-21)	21 (19-23)
Chel. movable digit	-	-	33 (33-35)	-	33 (32-34)	33	-	-	25 (23-27)	29 (25-30)
Chel. fixed digit	-	-	28 (28-30)	-	33 (31-34)	33	-	-	26 (25-27)	31 (27-33)
Nb of teeth / MD	-	3	3	3	3	3	1	-	1	1
Nb of teeth / FD	-	11	9-10	11	9-10	9	6	-	6	6

TABLE 3: 12S rRNA mean genetic distances (minimal and maximal values) of *Amblyseius swirskii* specimens collected in La Réunion Island and *Amblyseius swirskii* specimens from rearing units (Koppert)

	<i>Amblyseius swirskii</i> Koppert	<i>Amblyseius swirskii</i> La Réunion
<i>Amblyseius swirskii</i> Koppert	0.014 (0.003 - 0.027)	-
<i>Amblyseius swirskii</i> La Réunion	0.017 (0.003 - 0.0036)	0.004 (0 - 0.010)

ing Megabase 1000 apparatus. The sequences were compared to previously published sequences using BLAST and aligned with CodonCode Aligner (4.0.4.) (CodonCode, Inc., Centerville, MA, USA). The distance matrix was constructed using the Kimura 2-Parameter model using Mega 6.0 (Tamura *et al.* 2013). Genbank Accession Numbers are indicated in Table 1.

RESULTS

Morphological analyses

For the females, except for some slightly longer (*s4*) or shorter (*Sge I*) setae and some slightly shorter dimensions of the sternal and genital shields in the La Réunion population, the measurements were very close to all those reported in the original description and further re-descriptions (Table 2). Clearly the differences observed fall into the intraspecific variation as defined in Tixier (2012). Males of the La Réunion population have slightly longer *S4*, *Sge II*, *Sge III* and *Sti III* and shorter *Sge I* and *JV5* (Table 2). Morphological comparisons seem to show that specimens found in La Réunion belong to the species *A. swirskii*.

Molecular analyses

A fragment of 418 bp was amplified. The mean genetic distance (1.7 %) between specimens collected in La Réunion Island and specimens of *A. swirskii* from Koppert was low. Genetic distances range between 0.3 and 3.6 % (Table 3). Such values are similar to distances observed between specimens of the Koppert population. Furthermore, such distances clearly correspond to intraspecific distances reported for other species of Phytoseiidae (e.g. Okassa *et al.* 2009, 2011; Tixier *et al.* 2011, 2012,

2014). The molecular results thus confirm that the specimens collected in La Réunion Island belong to *A. swirskii*.

Discussion and conclusion

Molecular and morphological results both allow us to conclude that specimens collected in La Réunion Island belong to the species *A. swirskii*. The origin of the population collected in La Réunion Island remains unknown. The population may originate from previous releases of a commercial strain of *A. swirskii* coming from Europe. *Amblyseius swirskii* has however been reported from another island far away from a continent: Cape Verde, in 1992 (Ueckermann 1992), far before it was sold and used in large numbers in many countries. It can also have come "naturally" or by human commercial activities from Eastern Africa directly or via Madagascar and/ or Mauritius.

Several species of thrips and whiteflies occur in vegetable and ornamental crops in greenhouses in La Réunion (Vayssières *et al.* 2001), along with the broad *Polyphagotarsonemus latus* (Banks), and the external demands for alternatives to chemical control are increasing. The potential for development of this indigenous population of *A. swirskii* as a bio-control agent for La Réunion crops, mainly in greenhouses but possibly also in outdoor crops such as citrus orchards (Juan-Blasco *et al.* 2012), is therefore very high.

ACKNOWLEDGEMENTS

We are very grateful to Ingrid Avril (EARL Le Montvert, 77 Chemin Grand-Père, 97410 Saint-Pierre) the producer who has found the species on peppers and has had the intuition of its importance. We thank also Jean-Sébastien Cottineau, Technical

Manager in Arneflhor, and Jacques Fillatre, responsible of horticultural, strawberry and Papam production at Arneflhor for their investments in the collection and identification of the species. We are very grateful to the staff of Koppert BV (Koppert BV, Veilingweg 14, 2651 BE Berkel en Rodenrijs, The Netherlands) and especially to Dr Markus Knapp for providing us with specimens of the commercial strain of *Amblyseius swirskii*.

REFERENCES

- Abo-Shnaf R.I.A., Moraes G.J. de. 2014 — Phytoseiid mites (Acari: Phytoseiidae) from Egypt, with new records, descriptions of new species, and a key to species — *Zootaxa* 3865(1): 1-71.
- Anonymous 2012 — Décret n°2012-140 du 30 janvier 2012 relatif aux conditions d'autorisation d'entrée sur le territoire et d'introduction dans l'environnement de macroorganismes non indigènes utiles aux végétaux, notamment dans le cadre de la lutte biologique — *Journal Officiel de la République Française* 26 (texte n° 48), Réf. AGRG1124788D, 31 I 2012: 1803.
- Athias-Henriot C. 1975 — Nouvelles notes sur les Amblyseiini. II. Le relevé organotaxique de la face dorsale adulte (Gamasides, Phytoseiidae) — *Acarologia* 27: 20-29.
- Basha A.E., Yousef A.A., Ibrahim M.H., Mostafa E.M. 2001 — Five new phytoseiids from Egypt (Acari: Gamasida: Phytoseiidae) — *Al-Azhar J. Agricult. Res.* 33: 371-386.
- Buitenhuis R., Murphy G., Shipp L. and Scott-Dupree C. 2015 — *Amblyseius swirskii* in greenhouse production systems: a floricultural perspective — *Exp. Appl. Acarol.* 65(4): 451-464 DOI: 10.1007/s10493-014-9869-9 doi:10.1007/s10493-014-9869-9
- Calvo F.J., Knapp M., van Houten Y.M., Hoogerbrugge H., Belda J.E. 2015 — *Amblyseius swirskii*: what made this predatory mite such a successful biocontrol agent? — *Exp. Appl. Acarol.* 65(4): 419-433. doi:10.1007/s10493-014-9873-0
- Chant D.A., McMurtry J.A. (2007) — Illustrated Keys and Diagnoses for the Genera and Subgenera of the Phytoseiidae of the World (Acari: Mesostigmata) — Indira Publishing House, West Bloomfield, Michigan, USA, 220 pp.
- Chant D.A., Yoshida-Shaul E. 1991 — Adult ventral setal patterns in the family Phytoseiidae (Acari: Gamasina) — *Int. J. Acarol.* 17(3): 187-199. doi:10.1080/01647959108683906
- Cock M.J.W., van Lenteren J.C., Brodeur J., Barratt B.I.P., Bigler F., Bolckmans K., Consoli F.L., Haas F., Mason P.G., Parra J.R.P. 2010 — Do new access and benefit sharing procedures under the convention on biological diversity threaten the future of biological control? — *BioControl* 55: 199-218. doi:10.1007/s10526-009-9234-9
- Demite P.R., Moraes G.J. de, McMurtry J.A., Denmark H.A., Castilho R.C. 2016 — Phytoseiidae Database. Available from: www.lea.esalq.usp.br/phytoseiidae
- El-Badry E.A. 1967 — Five new phytoseiid mites from U.A.R., with collection notes on three other species (Acarina: Phytoseiidae) — *Indian J. Entomol.* 29: 177-184.
- Ferragut F., Pérez Moreno I., Iraola V., Escudero A. 2010 — *Acaros depredadores en las plantas cultivadas*. Familia Phytoseiidae — Agrotécnicas Ed, 202 pp.
- Jeyaprakash A., Hoy M.A. 2002 — Mitochondrial 12S rRNA sequences used to design a molecular ladder assay to identify six commercially available phytoseiids — *Biol. Cont.* 25: 136-142. doi:10.1016/S1049-9644(02)00056-7
- Juan-Blasco M., Qureshi J.A., Urbaneja A., Stansley P.A. 2012 — Predatory mite, *Amblyseius swirskii* (Acari Phytoseiidae), for biological control of Asian citrus psyllid, *Diaphorina citri* (Hemiptera: Psyllidae) — *Fla Entomol.* 95: 543-551. doi:10.1653/024.095.0302
- Kanouh M., Tixier M.-S., Okassa M., Kreiter S. 2010 — Phylogenetic and biogeographic analysis of the genus *Phytoseiulus* (Acari: Phytoseiidae) — *Zool. Script.* 39: 450-461. doi:10.1111/j.1463-6409.2010.00439.x
- Kreiter S., Ueckermann E.A., Quilici S. 2002 — Seven new phytoseiid species, with a generic assignment and a key to the species of La Réunion Island (Acari: Mesostigmata) — *Acarologia* 42(4): 335-350.
- Lindquist E., Evans G.W. 1965 — Taxonomic concepts in the Ascidae, with a modified setal nomenclature for the idiosoma of the Gamasina (Acarina: Mesostigmata) — *Mem. Entomol. Soc. Canada* 47: 1-64. doi:10.4039/entm9747fv
- McMurtry J.A., Moraes G.J. de, Sourasso N.F. 2013 — Revision of the life styles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies — *Syst. Appl. Acarol.* 18: 297-320.
- Okassa M., Tixier M.-S., Cheval B., Kreiter S. 2009 — Molecular and morphological evidence for new species status within the genus *Euseius* (Acari: Phytoseiidae) — *Canad. J. Zool.* 87: 689-698. doi:10.1139/Z09-057
- Okassa M., Kreiter S., Guichou S., Tixier M.-S. 2011 — Molecular and morphological boundaries of the predator *Neoseiulus californicus* McGregor (Acari: Phytoseiidae) — *Biol. J. Linn. Soc.* 104: 393-406.

- Porath A., Swirski E. 1965 — A survey of phytoseiid mites (Acarina: Phytoseiidae) on citrus, with a description of one new species — *Isr. J. Agric. Res.* 15: 87-100.
- Pritchard A.E., Baker E.W. 1962 — Mites of the family Phytoseiidae from Central Africa, with remarks on the genera of the world — *Hilgardia* 33(7): 205-309.
- Quilici S., Kreiter S., Ueckermann E. A., Vincenot D. 1997 — Predatory mites (Acari) from various crops on Réunion Island — *Intern. J. Acarol.* 23(4): 283-291. [doi:10.1080/01647959708683578](https://doi.org/10.1080/01647959708683578)
- Quilici S., Ueckermann E. A., Kreiter S., Vayssières J.-F. 2000 — Phytoseiidae (Acari) of La Réunion Island — *Acarologia* 41(1-2): 97-108.
- Rowell H.J., Chant D.A., Hansell R.I.C. 1978 — The determination of setal homologies and setal patterns on the dorsal shield in the family Phytoseiidae (Acarina: Mesostigmata) — *Canad. Entomol.* 110: 859-876. [doi:10.4039/Ent110859-8](https://doi.org/10.4039/Ent110859-8)
- Tamura K., Dudley J., Nei M., Kumar S. 2007 — MEGA4: Molecular Evolutionary Genetics Analysis (MEGA) software version 4.0 — *Molecular Biology and Evolution* 24: 1596-1599. [doi:10.1093/molbev/msm092](https://doi.org/10.1093/molbev/msm092)
- Tixier M.-S. 2012 — Approaches to assess intraspecific variations of morphological continuous characters: the case study of the family Phytoseiidae (Acari: Mesostigmata) — *Cladistics* 28(5): 489-502. [doi:10.1111/j.1096-0031.2012.00394.x](https://doi.org/10.1111/j.1096-0031.2012.00394.x)
- Tixier M.-S., Okassa M., Kreiter S. 2012 — An integrative morphological and molecular diagnostics for *Typhlodromus pyri* (Phytoseiidae) — *Zool. Script.* 41: 68-78. [doi:10.1111/j.1463-6409.2011.00504.x](https://doi.org/10.1111/j.1463-6409.2011.00504.x)
- Tixier M.-S., Okassa M., Liguori M., Poinso A., Salerno B., Kreiter S. 2010 — Voucher specimens for DNA sequences of phytoseiid mites (Acari: Mesostigmata) — *Acarologia* 50: 487-494. [doi:10.1051/acarologia/20101984](https://doi.org/10.1051/acarologia/20101984)
- Tixier M.-S., Otto J., Kreiter S., Vicente V., Beard J. 2014 — Is *Neoseiulus wearnei* the *Neoseiulus californicus* of Australia? — *Exp. Appl. Acarol.* 62: 267-277. [doi:10.1007/s10493-013-9740-4](https://doi.org/10.1007/s10493-013-9740-4)
- Tixier M.-S., Tsolakis H., Ragusa S., Poinso A., Ferrero M., Okassa M., Kreiter S. 2011 — An integrative taxonomical approach demonstrates the synonymy between *Cydnodromus idaeus* and *C. picanus* — *Invert. Syst.* 25: 273-281.
- Ueckermann E.A. 1992 — Some Phytoseiidae of the Cape Verde Islands (Acari: Mesostigmata) — *Phytophylactica* 24: 145-155.
- Vayssières J.-F., Delvare G., Maldas J.-M., Aberlenc H.-P. 2001 — Inventaire préliminaire des arthropodes ravageurs et auxiliaires des cultures maraîchères sur l'île de la Réunion — *Intern. J. Trop. Insect Science* 21: 11-22.
- van Lenteren J.C. 2012 — The state of commercial augmentative biological control: plenty of natural enemies, but a frustrating lack of uptake — *BioControl.* 57(1): 1-20.
- van Lenteren J.C., Bueno V.H.B.P. 2003 — Augmentative biological control of arthropods in Latin America — *BioControl.* 48: 123-139. [doi:10.1023/A:1022645210394](https://doi.org/10.1023/A:1022645210394)
- Wright R.J. 2004 — Retail suppliers of beneficial organisms — Nebraska Cooperative Extension NF94-182, Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, <http://ianrpubs.unl.edu/insects/nf182.htm>
- Zannou I.D., Hanna R. 2011 — Clarifying the identity of *Amblyseius swirskii* and *Amblyseius rykei* (Acari: Phytoseiidae): are they two distinct species or two populations of one species? *Exp. Appl. Acarol.* 53: 339-347. [doi:10.1007/s10493-010-9412-6](https://doi.org/10.1007/s10493-010-9412-6)
- Zannou I.D., Moraes G.J. de, Ueckermann E.A., Oliveira A.R., Yaninek J.S., Hanna R. 2007 — Phytoseiid mites of the sub-tribe Amblyseiina (Acari: Phytoseiidae: Amblyseiini) from sub-Saharan Africa — *Zootaxa*, 1550: 1-47.

COPYRIGHT

Kreiter S. *et al.* Acarologia is under free license. This open-access article is distributed under the terms of the Creative Commons-BY-NC-ND which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original author and source are credited.