

This article was downloaded by: [Miss Ibtissem Ben Fekih]

On: 07 August 2015, At: 07:27

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: 5 Howick Place, London, SW1P 1WG



Annales de la Société entomologique de France (N.S.): International Journal of Entomology

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tase20>

First survey on ecological host range of aphid pathogenic fungi (Phylum Entomophthoromycota) in Tunisia

Ibtissem Ben Fekih^{ab}, Sonia Boukhris-Bouhachem^a, Mohamed Bechir Allagui^a, Annette Bruun Jensen^c & Jørgen Eilenberg^c

^a Plant Protection Laboratory of National Institute of Agricultural Research of Tunisia, Rue Hédi Karray, 2049 Ariana, Tunisia

^b National Institute of Agronomy of Tunisia, University of Carthage, 43, Avenue Charles Nicolle, 1082 Cité Mahrajène, Tunisia

^c Department of Plant and Environmental Sciences, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg, Denmark

Published online: 06 Aug 2015.



[Click for updates](#)

To cite this article: Ibtissem Ben Fekih, Sonia Boukhris-Bouhachem, Mohamed Bechir Allagui, Annette Bruun Jensen & Jørgen Eilenberg (2015): First survey on ecological host range of aphid pathogenic fungi (Phylum Entomophthoromycota) in Tunisia, *Annales de la Société entomologique de France (N.S.): International Journal of Entomology*

To link to this article: <http://dx.doi.org/10.1080/00379271.2015.1059997>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

First survey on ecological host range of aphid pathogenic fungi (Phylum Entomophthoromycota) in Tunisia

Ibtissem Ben Fekih^{a,b,*}, Sonia Boukhris-Bouhachem^a, Mohamed Bechir Allagui^a, Annette Bruun Jensen^c & Jørgen Eilenberg^c

^aPlant Protection Laboratory of National Institute of Agricultural Research of Tunisia, Rue Hédi Karray, 2049 Ariana, Tunisia; ^bNational Institute of Agronomy of Tunisia, University of Carthage, 43, Avenue Charles Nicolle, 1082 Cité Mahrajène, Tunisia; ^cDepartment of Plant and Environmental Sciences, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg, Denmark

(Accepté le 21 mai 2015)

Summary. The natural occurrence of fungal pathogens of aphids and their ecological host range was investigated in Tunisia from 2009 to 2012. The survey focused on aphid infesting different crops and weeds and included 10 different aphid species. Samples were collected from eight agricultural crops sites belonging to three different bioclimatic zones. Four pathogens from the phylum Entomophthoromycota were found to occur naturally in Tunisian ecosystems: *Pandora neoaphidis* (Entomophthorales: Entomophthoraceae), *Entomophthora planchoniana* (Entomophthorales: Entomophthoraceae), *Conidiobolus obscurus* (Entomophthorales: Ancylistaceae) and *Neozygites fresenii* (Neozygiales: Neozygiteaceae). The occurrence of entomophthoralean fungi depended on the sampling area, the bioclimatic zone, and aphid species. *P. neoaphidis* and *E. planchoniana* were the predominant pathogens infecting a wide range of aphid species whereas *C. obscurus* and *N. fresenii* were sporadically present on a limited number of aphid species. This study is the first survey on ecological host range of entomophthoralean fungi in Tunisia, and the first documentation of *C. obscurus* and *N. fresenii* to occur in Tunisia and Maghreb Region.

Résumé. Première étude écologique de la gamme d'hôtes de pathogènes (Phylum Entomophthoromycota) de pucerons en Tunisie. L'observation des champignons pathogènes de pucerons et de leur gamme d'hôtes dans l'écosystème agricole tunisien a été menée durant quatre années de 2009 à 2012. Les prospections ont porté sur dix espèces de pucerons inféodées à plusieurs cultures et mauvaises herbes. Les échantillons ont été prélevés dans huit sites appartenant à différentes zones bioclimatiques. Quatre espèces fongiques du phylum Entomophthoromycota ont été répertoriées : *Pandora neoaphidis* (Entomophthorales : Entomophthoraceae), *Entomophthora planchoniana* (Entomophthorales : Entomophthoraceae), *Conidiobolus obscurus* (Entomophthorales : Ancylistaceae) et *Neozygites fresenii* (Neozygiales : Neozygiteaceae). L'occurrence des espèces fongiques est variable selon la station d'échantillonnage, la zone bioclimatique et l'espèce de puceron. *P. neoaphidis* et *E. planchoniana* sont les pathogènes majeurs infectant un large éventail d'espèces tandis que *C. obscurus* et *N. fresenii* sont sporadiquement observées sur un nombre limité d'espèces. Ceci est la première étude écologique de la gamme d'hôtes des champignons entomophthorales en Tunisie, avec le premier signalement de *C. obscurus* et *N. fresenii* en Tunisie et au Maghreb.

Keywords: Entomophthoralean fungi; epizootics; occurrence; seasonal infection; biological control

Aphids (Hemiptera: Aphididae) are worldwide pests of forestry, agricultural and horticultural crops (Blackman & Eastop 1984). They cause direct damage as phloem feeders and indirect damage by depositing honeydew and transmitting plant viruses (Brault et al. 2007; Dedryver et al. 2010). In Tunisia, aphids are among the most serious pests in agriculture (Jarraya 2003; Boukhris-Bouhachem et al. 2007; Harbaoui et al. 2008). Entomopathogenic fungi are some of the most important natural enemies of aphids. In temperate climatic zones, most aphid pathogens found belong to the phylum Entomophthoromycota (Humber 2012) and so far 30 entomophthoralean species have been described to infect aphids (Barta & Cagan 2006a). Most of these species are obligate aphid

pathogens from the orders Entomophthorales and Neozygiales (Humber 2012). They often cause epizootics within their host population, which makes them interesting as future agents for biological control (Eilenberg 2002; Steinkraus 2006; Keller 2007). Entomophthoralean fungi have been found worldwide on aphids (Hatting et al. 2000; Barta & Cagan 2006a, 2006b; Scorsetti et al. 2007); however, very limited information about insect pathogenic fungi on aphids from the Maghreb Region and the rest of North Africa is available (Abdel-Mallek et al. 2004). In Tunisia, so far, only two Entomophthorales species, *Pandora neoaphidis* (Remaudière & Hennebert) and *Entomophthora planchoniana* Cornu have been reported to infect *Sitobion avenae* (Fabricius) and *Myzus persicae* Sulzer

*Corresponding author. Email: fekih.ibtissem@gmail.com

(Ben Fekih et al. 2013). In this paper, we provide for the first time information on the natural occurrence and ecological host range of entomophthoralean fungi on aphids on agriculturally important crops and weeds sampled from several localities in three different climatic conditions over four years in Tunisia.

Material and methods

Sampling sites

The survey was conducted in eight localities in Tunisia (Figure 1) belonging to three different climatic zones (Table 1). Sampling was done weekly in two localities at the northeast coast (Soliman, semi-arid zone and Douala, sub-humid zone), fortnightly in one locality in the northwest (Beja, sub-humid zone) and in one locality in the center of the country (Kairouan, arid zone). Occasionally the investigation involved four additional sites: Tunis (experimental and garden of the National Institute of Agricultural Research), Manouba and two other localities in the western part of Tunisia (Bousalem and Kef).

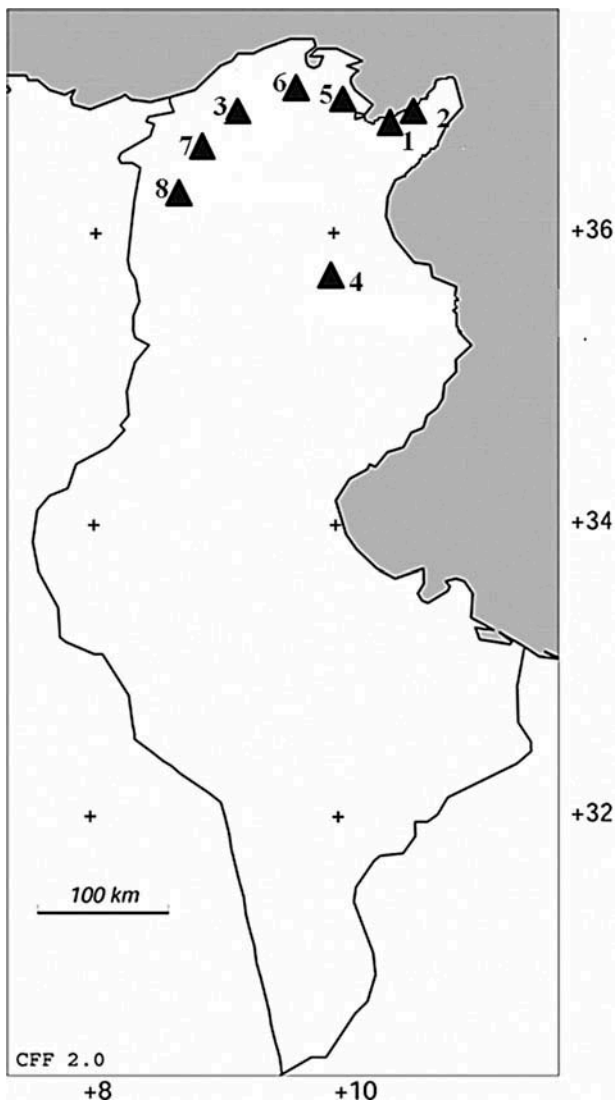


Figure 1. Geographical locations of aphid sampling sites.

Table 1. Sampling sites.

Code	Sampling site	Geographical coordinates	Climatic zone
1	Soliman	36°42'53"N, 10°29'00"E	Semi-arid
2	Douala	36°47'33"N, 10°37'46"E	Sub-humid
3	Beja	36°44'06"N, 9°11'00"E	Sub-humid
4	Kairouan	35°40'46"N, 10°05'29"E	Arid
5	Tunis (INRAT)	36°48'47"N, 10°10'53"E	Semi-arid
6	Manouba	36°48'37"N, 10°06'43"E	Semi-arid
7	Bousalem	36°37'09"N, 8°57'59"E	Sub-humid
8	Kef	36°11'08"N, 8°42'52"E	Semi-arid

Aphid species sampled

Aphids were sampled at regular intervals from potato, peach, and barley, to look for entomophthoralean infection, while more occasionally aphids associated to Faba bean, wheat, pepper and weeds (sow thistles) were sampled. The sampling included in total 10 aphid species from the family Aphididae: *Rhopalosiphum padi* (L.), *Sitobion avenae*, *Rhopalosiphum maidis* (Fitch), *M. persicae*, *Aphis gossypii* Glover, *Macrosiphum euphorbiae* (Thomas), *Aphis fabae* (Scopoli), *Acyrtosiphon pisum* (Harris), *Aphis craccivora* Koch, and *Hyperomyzus lactucae* (L.). Sampling was performed from February to December over a four-year period from 2009 to 2012, with the most intensive sampling being performed between March to June each year due to the aphid infestation season on the target crops (potato, peach and barley). Depending on the crop, 30 to 50 samples (leaves, stems or ears) infested with aphids were sampled randomly, kept in ventilated boxes and brought to the laboratory for microscope examination.

Fungal identification

Under binocular microscope, living aphids were picked up, placed individually in plastic cups of 30 ml containing 1.5% of water-agar and prepared for incubation at 20°C under LD 18:6 h. Plant material was observed under binocular microscope for up to seven days to allow the fungus development in the infected aphids. Both aphid cadavers covered with visible fungal structures and dead aphids with no external sign were carefully removed from the plant substrate using sterile fine forceps for further examination. The descending conidia method, described by Papierok and Hajek (1997), was used to collect primary and secondary conidia. Aphid cadavers (either with or without external sign of fungal infection) were placed on a glass slide in Petri dishes of 90 mm diameter with a filter paper moistened with distilled water. Incubation was conducted from 5 to 48 h at 20°C to allow development of conidiophores through the cuticle and discharge of conidia. The discharged conidia were mounted in lactic acid, and the size and shape of primary and secondary conidia were recorded using an Olympus microscope at 400× magnification. Subsequently the fungi were identified using the key by Keller (2006).

Results

Fungal identification

From a total of 5460 sampled aphids, 3256 cadavers were recorded to have been killed by fungi from the phylum Entomophthoromycota. Four entomophthoralean species were found: *P. neoaphidis* and *E. planchoniana*,

previously reported to occur naturally in Tunisia (Ben Fekih et al. 2013), and two entomophthoralean species documented for the first time:

- (1) *Conidiobolus obscurus* (Hall & Dunn) Remaudière & Keller (Entomophthorales, Ancylistaceae), characterized by globose primary conidia with pointed papilla and a rounded tip. We measured primary conidia to be on average $32.6 \pm 1.2 \times 26.3 \pm 1.4 \mu\text{m}$. The secondary conidia, morphologically similar to primary conidia, were on average $29.3 \pm 1.4 \times 25.4 \pm 0.5 \mu\text{m}$. Conidiophores were simple, unbranched. The conidia are thus within the range of measurement for *C. obscurus* provided by Keller (2006), who reported primary conidia to be $29\text{--}53 \times 23\text{--}47 \mu\text{m}$ and secondary conidia to be $29\text{--}41 \times 24\text{--}35 \mu\text{m}$.
- (2) *Neozygites fresenii* (Nowakowski) Remaudière & Keller (Neozygiales, Neozygitaceae). The pyriform primary conidia with a flattened base were on average $22.7 \pm 1.6 \times 16.6 \pm 0.6 \mu\text{m}$. Secondary conidia were attached to a capillary conidiophores arising from primary conidia, and measured on average $29.3 \pm 2.1 \times 13.1 \pm 0.9 \mu\text{m}$. The conidia were thus little longer in comparison to measurements provided by Keller (2006), who reported primary conidia to be $18.2\text{--}21.5 \times 14.5\text{--}17.8 \mu\text{m}$, and secondary conidia to be $19.7\text{--}27.2 \times 11.2\text{--}13.7 \mu\text{m}$.

Seasonal prevalence and ecological host range

Seasonal prevalence

Seasonal infection with fungi was observed during the sampling period to reach epizootic development in April and May. The first entomophthoralean infections were recorded in March and fungal prevalence lasted to June. However, a few cases of fungal infection were recorded as late as in December. The frequency of the entomophthoralean species varied with the sampling locality (bioclimatic zone) (Figure 2). From the 3256 infected cadavers, *P. neoaphidis* and *E. planchoniana* were in general the most common fungal pathogens found, representing 67.1% and 32.3% of all the infected aphids, respectively. *P. neoaphidis* was recorded in all regions through mid-March to beginning of June. Almost half of the aphids collected in Soliman were infected by entomophthoralean fungi: 48.7% of 890 infected cadavers gathered throughout the whole sampling season. *E. planchoniana* was recorded in six different localities from April to mid-June, reaching a highest and dominant position in Kairouan (arid zone) with 40.7% of 647 infected cadavers. *C. obscurus* and *N. fresenii*, which never were reported from Tunisia before, were sporadically observed during our survey since 2011 but they never reached high prevalence. *C. obscurus* was recorded in three localities: Soliman (0.3%), Douala (0.7%) and Kairouan (0.1%) during May 2011 and June 2012. Infection with *N. fresenii* was recorded for the first time in February 2011. During the sampling season, the pathogen was recorded during April 2011 in Douala (0.3%) and May–June of 2011 in Beja (0.1%).

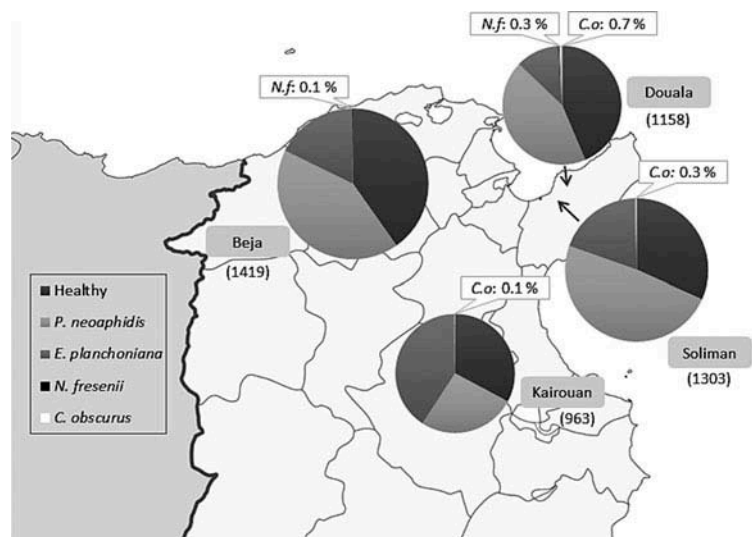


Figure 2. Relative frequency of entomophthoralean fungi on the main sampling sites of aphids. Number of sampled aphids is represented in the figure. Both *Neozygites fresenii* (*N.f*) and *Conidiobolus obscurus* (*C.o*) occur at low level. Percentage of each sporadic fungus is represented according to the site.

Table 2. Ecological host range of entomophthoralean fungal species infecting aphids in Tunisia.

Aphid species	Host plant	Sampling year(s)	No sampled aphids	No infected aphids	<i>P. neoaphidis</i>	<i>E. planchoniana</i>	<i>N. fresenii</i>	<i>C. obscurus</i>
<i>Aphis craccivora</i>	Faba bean	2011	62	39	33	6	0	0
<i>Aphis fabae</i>	Faba bean	2010–2011	382	115	111	0	4	0
<i>Aphis gossypii</i>	Potato	2010	36	25	25	0	0	0
<i>Acyrtosiphon pisum</i>	Faba bean	2011	82	23	23	0	0	0
<i>Hyperomyzus lactucae</i>	Sow thistle	2011	20	8	8	0	0	0
<i>Myzus persicae</i>	Peach, potato, pepper	2009–2012	2241	1480	864	607	0	9
<i>Macrosiphum euphorbiae</i>	Potato	2010–2011	57	27	27	0	0	0
<i>Rhopalosiphum maidis</i>	Barley	2011	80	20	12	8	0	0
<i>Rhopalosiphum padi</i>	Barley	2009–2012	890	519	402	111	2	4
<i>Sitobion avenae</i>	Barley	2009–2012	1610	1000	680	320	0	0

Ecological host range

The ecological host range differed between the fungal species found (Table 2). *P. neoaphidis* was in general predominant and was found on all aphid species. *E. planchoniana* was observed on cereal associated aphids (*R. padi*, *S. avenae*, and *R. maidis*), the green peach aphid (*M. persicae*) and the cowpea aphid (*A. craccivora*). *C. obscurus* was recorded from *M. persicae* and *R. padi* only and *N. fresenii* was recorded from *A. fabae* and *R. padi* only.

Discussion

This four-year survey gave significant new knowledge about the natural occurrence and ecological host range of entomophthoralean fungi in Tunisia. In total, four different species from the two orders Entomophthorales and Neozygiales were identified from aphids infesting agricultural crops and weeds. This survey shows that in Tunisian ecosystems, *P. neoaphidis* is the most abundant pathogen, followed by *E. planchoniana*, *C. obscurus* and *N. fresenii*. *P. neoaphidis* and *E. planchoniana* were documented on *S. avenae* and *M. persicae*, confirming the findings by Ben Fekih et al. (2013). In the current study both the number of aphid hosts and the sampling areas (adding coastal and northwest regions) were expanded to get an understanding of the natural occurrence of entomophthoralean fungi infecting important pest aphids in time and space. *P. neoaphidis* and *E. planchoniana* are both widely distributed in Europe, North and South Africa, North and South America and Asia (Hatting et al. 2000; Abdel-Mallek et al. 2004; Barta & Cagan 2006a, 2006b; Scorsetti et al. 2007; Ben Fekih et al. 2013). The two widespread species, *P. neoaphidis* and *E. planchoniana*, were found in all three bioclimatic zones: sub-humid, semi-arid and arid. *P. neoaphidis* was

predominant in the sub-humid and semi-arid zones, and *E. planchoniana* was most abundant in the arid zone (Kairouan). The natural occurrence of both fungi according to abiotic factors (humidity and temperature) seems to be in agreement with previous reports where *P. neoaphidis* was found more commonly in areas with high relative humidity and moderate temperatures, while *E. planchoniana* was found more commonly in dry and less humid environments (Nielsen et al. 2001; Barta & Cagan 2006a, 2006b). *P. neoaphidis* in Tunisia had a longer infection season, starting in autumn (October–November), but seems to be more common in spring and infections could be found until the beginning of summer (early June). The infection season of *E. planchoniana* was shorter than of *P. neoaphidis*. The first occurrence of *E. planchoniana* was recorded in spring and lasted until mid-June, and like *P. neoaphidis*, *E. planchoniana* had the ability to establish epizootics within its host population.

This study reports, for the first time, *C. obscurus* on *M. persicae* and *R. padi* in Tunisia. The pathogen has already been recorded in North Africa (Egypt), South Africa, North and South America and Europe (Hatting et al. 2000; Abdel-Mallek et al. 2004; Barta & Cagan 2006b; Scorsetti et al. 2007). *C. obscurus* occurs at low levels within populations of *M. persicae* and *R. padi* (Table 2), and was not able to develop epizootic during the four years this study lasted. *C. obscurus* had the same infection season as *E. planchoniana*, a pattern previously documented by Barta & Cagan (2006a).

N. fresenii was also reported for the first time in Tunisia, on *A. fabae* and *R. padi* (Table 2). The pathogen was recorded in coastal region (Douala) and in the northwest region (Beja), both in the sub-humid zone. *N. fresenii* has a global distribution (Remaudière et al. 1981; Silvie & Papierok 1991; Sewify 2000; Barta & Cagan 2006a; Scorsetti et al. 2007). Like for *C. obscurus* we never observed epizootic development of *N. fresenii*. Interestingly, previous

studies from other countries highlighted the potential of *N. fresenii* to establish epizootics among aphid populations in hot, humid and almost tropical conditions (Steinkraus 1998; Barta & Cagan 2006a; Keller 2006).

Conclusion

Our study highlights the natural occurrence of entomophthoralean fungi on aphids in different bioclimatic zones of Tunisia. *P. neoaphidis* and *E. planchoniana* are the major aphid pathogens of aphids. *C. obscurus* and *N. fresenii* are new records for Tunisia and the Maghreb Region. The occurrence of entomophthoralean species seems to be affected by their ecological habitat (abiotic factors, the aphid host species and the plant host). Therefore, it will be interesting to cover the full spectrum of entomophthoralean fungi infecting aphids in Tunisia by stratified quantitative sampling in time and space.

References

- Abdel-Mallek AY, Abdel-Rahman MAA, Omar SA, Hamam GHA. 2004. A comparative abundance of entomopathogenic fungi of cereal aphids in Assiut, Egypt. In: Proceedings of the 2nd Saudi Science Conference, Faculty of Science, King Abdulaziz University. 15–17 March, Part 1; p. 167–174.
- Barta M, Cagan L. 2006a. Observations on the occurrence of Entomophthorales infecting aphids (Aphidoidea) in Slovakia. *BioControl* 51:795–808.
- Barta M, Cagan L. 2006b. Aphids-pathogenic Entomophthorales (their taxonomy, biology and ecology). *Biologia*. 61:543–616.
- Ben Fekih I, Boukhris-Bouhachem S, Eilenberg J, Allagui MB, Jensen AB. 2013. The occurrence of two species of Entomophthorales (Entomophthoromycota), pathogens of *Sitobion avenae* and *Myzus persicae* (Hemiptera: Aphididae), in Tunisia. *BioMed Research International*, Article ID 838145, p. 1–7. <http://dx.doi.org/10.1155/2013/838145>
- Blackman RL, Eastop VF. 1984. Aphids on the world's crops: an identification and information guide. Chichester, UK: John Wiley & Sons.
- Boukhris-Bouhachem S, Souissi R, Turpeau E, Rouzé-Jouan J, Fahem M, Ben Brahim N, Hullé M. 2007. Aphid (Hemiptera: Aphidoidea) diversity in Tunisia in relation to seed potato production. *Annales de la Société entomologique de France (N.S.)*. 43:311–318.
- Brault V, Herrbach E, Reinbold C. 2007. Electron microscopy studies on luteovirid transmission by aphids. *Micron*. 38:302–312.
- Dedryver CA, Le Ralec A, Fabre F. 2010. The conflicting relationships between aphids and men: a review of aphid damage and control strategies. *Comptes Rendus Biologies*. 333:539–553.
- Eilenberg J. 2002. Biology of fungi from the order Entomophthorales [PhD thesis]. Copenhagen, Denmark: Department of Ecology, The Royal Veterinary and Agriculture University.
- Harbaoui H, Mezghani KM, Marrakchi M, Makni M, Makni H. 2008. Etude morphologique et toxicologique des pucerons (homoptères: aphididae) des céréales en Tunisie. *Bulletin de la Société Zoologique de France*. 133:203–213.
- Hatting JL, Poprawski TJ, Miller RM. 2000. Prevalences of fungal pathogens and other natural enemies of cereal aphids (Homoptera: Aphididae) in wheat under dryland and irrigated conditions in South Africa. *BioControl*. 45:179–199.
- Humber RA. 2012. *Entomophthoromycota*: a new phylum and reclassification for entomophthoroid fungi. *Mycotaxon*. 120:477–492.
- Jarraya A. 2003. Principaux nuisibles des plantes cultivées et des denrées stockées en Afrique du Nord. Leur biologie, leurs ennemis naturels, leurs dégâts et leur contrôle. Tunis: Climat Pub.
- Keller S. 2006. Entomophthorales attacking aphids with a description of two new species. *Sydowia*. 58:38–74.
- Keller S. 2007. Arthropod-pathogenic Entomophthorales: biology, ecology, identification. COST Action 842. Luxembourg: Office for Official Publications of the European Communities; p. 66–81.
- Nielsen C, Eilenberg J, Dromph K. 2001. Entomophthorales on cereal aphids: Characterisation, growth, virulence, epizootiology and potential for microbial control. Ministry of Environment and energy, Danish Environmental Protection Agency, Denmark, Copenhagen. *Pesticides Research*. 53:75.
- Papierok B, Hajek A. 1997. Fungi: Entomophthorales. In: Lacey L, editor. Manual of techniques in insect pathology. San Diego: Academic Press; p. 197–212.
- Remaudière G, Latgé JP, Michel MF. 1981. Ecologie comparée des entomophthoracées pathogènes de pucerons en France littorale et continentale. *Entomophaga*. 26:157–178.
- Scorsetti AC, Humber RA, Garcia JJ, Lastra CCL. 2007. Natural occurrence of entomopathogenic fungi (Zygomycetes: Entomophthorales) of aphid (Hemiptera: Aphididae) pests of horticultural crops in Argentina. *BioControl*. 52:641–655.
- Sewify GH. 2000. *Neozygites fresenii* causing epizootic in aphid (*Aphis craccivora* Koch.) population on faba bean in Egypt. *Bulletin of Faculty of Agriculture, University of Cairo*. 51:85–94.
- Silvie P, Papierok B. 1991. Les ennemis naturels d'insectes du cotonnier au Tchad: premières données sur les champignons de l'ordre des Entomophthorales. *Coton Fibres Tropicales*. 46:293–308.
- Steinkraus DC. 1998. The Neozygitaceae: Important small Arthropod specialists. Proceedings, VIIth International Colloquium on Invertebrate Pathology and Microbial Control; August 23–28; Sapporo; p. 258–262.
- Steinkraus DC. 2006. Factors affecting transmission of fungal pathogens of aphids. *Journal of Invertebrate Pathology*. 92:125–131.