

Occurrence of Entomopathogenic and Human Potentially Pathogenic Fungi in Carpet Dust from Mosques and Residential Houses

Hend A. Hussein¹ & Samir K. Abdullah^{1, 2*}

¹Biology Department, Faculty of Science, University of Zakho, Iraq

^{1, 2}Medical Laboratory Technology Department, Alnoor University College, Nineva, Iraq

*Corresponding author: samir.abdullah1947@gmail.com

Abstract: A limited work is currently available on the incidence of entomopathogenic and other potentially opportunistic pathogens in carpet dust in residential houses and mosques. The aim of the study was to isolate fungi from carpet dust using modified medium based on oatmeal agar (OTA) amended with cetyltrimethyl ammonium bromide (CTAB) and cyclohexamide. Identification of the species was based on the cultural and micro-morphological characteristics of their reproductive structures. The study revealed the isolation and identification of 30 species from carpet dust in houses and 24 species from carpet dusts in mosques in addition to yeasts and non-sporulating mycelia. Three entomopathogenic species assigned to *Beauveria bassiana*, *Metarhizium anisopliae* and *Purpureocillium lilacinum* were detected. Dermatophytes and related keratinophilic fungi were represented by species in the genera *Chrysosporium*, *Gymnoascus* and *Microsporium*. Several species of opportunistic pathogens that can tolerate a high level of cyclohexamide including species in the genera *Acaulium*, *Alternaria*, *Arthrographis*, *Aspergillus*, *Chaetomium*, *Cladosporium*, *Cunninghamella*, *Fusarium*, *Geomyces*, *Geotrichum*, *Microascus*, *Myceliophthora*, *Penicillium*, *Phaeoacremonium*, *Rhizopus*, *Scopulariopsis*, *Sordaria*, *Stachybotrys*, *Syncephalastrum* and *Trichoderma* were also detected.

Keywords: Carpet dust, Entomopathogenic fungi, Dermatophytes, Opportunistic fungi.

Introduction

Floor dust is a complex of both biological and chemical components. Chemical components is a highly heterogeneous mixture of inorganic and organic particles that incorporated in the products used by consumers (Santillo et al., 2003) as well as toxic substances that are produced by bacteria and fungi such as volatile fungal metabolites, 1, 3-B-glucan, ergosterols, mycotoxins and bacterial toxins (Wu et al., 2012; Skora et al., 2017). Biological contaminants included mites, bacteria, fungi, insect parts, pollens, protozoans and viruses. These biological agents can cause diseases only to people who are sensitive to them (Nevalainen & Seuri, 2005).

Floor dust can cause a variety of health problems such as the increase of risk of asthma (Jaakkola et al., 2002), respiratory allergies (De Ana et al., 2006), development of allergic rhinitis (Stark et al., 2005), pulmonary diseases (Kawel et al., 2011), increase in the hypersensitivity syndrome (Jacobs & Andrew, 2003) and mycoses (Weitzman & Summerbell, 1995).

Several studies have shown that the floor dust accumulated on fitted carpets are a suitable niche for the growth of several dermatophytes, related keratinophilic fungi, potentially pathogenic fungi and mycotoxin producing fungi (Beguin & Nolard, 1996; Bahkali & Parvez,

1999; Abdullah & Al-Musa, 2000; Al-Musa & Abdullah, 2001; Engelhart et al., 2002; Singh et al., 2009; Al-Humiany, 2010; Abdullah & Al-Musa, 2011).

The present study aimed to isolate and identify the entomopathogenic, potentially pathogenic for human and cyclohexamide resistant fungi from carpet dust using a modified medium.

Materials and Methods

Collection of Dust Samples

A total of 100 dusts samples (50 samples, for each of residential houses and mosques), were collected from different sites in Duhok province included Duhok center, Amadi, Summel, Zakho and Chira cities, during September, 2014 to May, 2015. Dust samples were taken from the surface of fitted carpets by the help of home vacuum cleaner. The samples were stored in sterilized collecting bags at 5°C and were processed within 1-2 weeks after collection.

Isolation Method

A selective medium used for isolation of entomopathogenic fungi as described by Pasudos et al. (2012) was modified to include Oatmeal Agar Medium (OTA) (30 g Quiker oat, 15 g agar, 1 L distilled water), 0.6 g/ l cetyltrimethyl ammonium bromide (CTAB), 0.5 g/ l cyclohexamide and 50 mg/ l chloramphenicol. Initial dilution was made by mixing 1 g of floor dust (as dry weight base) with 9 ml sterile distilled water in a test tube and one drop of Tween 80 was added and shaken thoroughly for 10 minutes. Serial dilutions up to 10^{-3} were made. Aliquots of 1 ml from 10^{-3} dilution were added to sterile Petri dishes (in triplicates) and about 20 ml of medium was poured over. Plates were incubated at 25°C for two weeks. Isolates from growing colonies were sub cultured on appropriate media for identification.

Identification of Fungi

The majority of detected species were identified to species level based on morphological and cultural characteristics. Keratinophilic and opportunistic pathogenic fungi were identified according to Oorschot (1980), Currah (1985), De Hoog & Guarro (1995), Guarro et al. (2012), Kidd et al. (2016) and Sandoval-Denis et al. (2016a, b). Entomopathogenic fungi were identified according to Tzean et al. (1997) and Bischoff et al. (2009). For other fungi, apart from *Aspergillus* and *Penicillium*, the manuals of Ellis (1971, 1976) and Domsch et al. (1980) were followed.

For identification of species in the genera *Aspergillus* and *Penicillium*, pure colonies were grown on four media according to Klich (2002) and Samson et al. (2000). The media are as follows: Czapek Yeast Extract Agar incubated for seven days at 25°C (CYA25), Czapek Yeast Extract Agar incubated for seven days at 37°C (CYA37), Czapek Yeast Extract Agar with 20% Sucrose incubated for seven days at 25°C (CY20S) and Malt Extract Agar was incubated for seven days at 25°C (MEA).

For each culture, four plates were used, two of CYA and one for each of CY20S and MEA. Each plate was inoculated at the center and incubated in the dark for seven days. One CYA was incubated at 37°C. The rest were incubated at 25°C. All species were identified according to the keys and descriptions provided by Pitt & Hocking (1997), Klich (2002), Samson et al. (2000, 2007) and Visagie et al. (2014a, b).

Measurements were taken after seven days incubation. Microscopic mounts were made in lacto phenol with or without cotton blue. For recognizing the ornamentations of the conidiophores and conidia, microscopic slides were examined with oil immersion.

Frequency of occurrence for each species was calculated according to the following equation:

$$\text{Frequency of occurrence (\%)} = \frac{\text{No. of samples on which a fungus appeared}}{\text{Total number of samples}} \times 100$$

Results and Discussion

A total of 39 species (30 species from the house dust and 24 species from the mosques dust) in addition to yeast and non-sporulating mycelia were isolated and identified using oatmeal agar medium (OMA) amended with 0.5 g/ l cycloheximide and 0.6 g/ l cetyltrimethyl ammonium bromide (CTAB) and 50 mg/ l chloramphenicol (Table 1). These fungi were categorized into three groups, dermatophytes and related keratinophilic fungi, entomopathogenic and other opportunistic pathogenic fungi. The first group included species in the genera *Chrysosporium*, *Gymnoascus* and *Microsporium*. The second group, entomopathogenic fungi were represented by three species: *Beauveria bassiana*, *Metarhizium anisopliae* and *Purpureocillium lilacinum*. The third group, opportunistic pathogenic fungi were represented by those species that can tolerate a higher level of cycloheximide including species in the genera *Acaulium*, *Alternaria*, *Arthrographis*, *Aspergillus*, *Chaetomium*, *Cladosporium*, *Cunninghamella*, *Fusarium*, *Geomyces*, *Geotrichum*, *Microascus*, *Myceliophthora*, *Penicillium*, *Phaeoacremonium*, *Rhizopus*, *Scopulariopsis*, *Sordaria*, *Stachybotrys*, *Syncephalastrum*, *Trichoderma* in addition to yeast and non-sporulating mycelia.

Table 1: Frequency isolation (F %) of Entomopathogenic and opportunistic fungi with Cycloheximide, CTAB and Oat meal.

Species	Houses		Mosques	
	No of positive samples	F (%)	No of positive samples	F (%)
Dermatophytes and related keratinophilic				
<i>Chrysosporium keratinophilum</i>	2	4	-	-
<i>C. pseudomerdarium</i>	3	6	1	2
<i>C. pannicola</i>	3	6	-	-
<i>C. tropicum</i>	7	14	3	6
<i>Gymnoascus reesii</i>	1	2	-	-
<i>G. devroeyi</i>	-	-	1	2
<i>Microsporium gypseum</i>	3	6	1	2
Entomopathogenic fungi				
<i>Beauveria bassiana</i>	4	8	8	8
<i>Metarhizium anisopliae</i>	5	10	-	-
<i>Purpureocillium lilacinum</i>	3	6	2	2
Other potentially pathogenic fungi				
<i>Acaulium acremonium</i>	1	2	-	-
<i>Alternaria alternata</i>	18	36	6	12
<i>Arthrographis kalrae</i>	3	6	3	6
<i>Aspergillus flavus</i>	17	34	6	12
<i>A. japonicus</i>	-	-	1	2
<i>A. niger</i>	17	34	5	10
<i>A. niveus</i>	-	-	1	2

<i>A. ochraceus</i>	7	14	-	-
<i>A. robustus</i>	-	-	2	4
<i>A. ustus</i>	1	2	-	-
<i>A. versicolor</i>	5	10	1	2
<i>Chaetomium longicolleum</i>	-	-	2	4
<i>C. madrasens</i>	-	-	1	2
<i>Cladosporium herbarum</i>	2	4	-	-
<i>Cunninghamella</i> sp.	2	4	1	2
<i>Fusarium</i> sp.	3	6	1	2
<i>Geomyces pannorum</i>	1	2	-	-
<i>Geotrichum candidum</i>	3	6	-	-
<i>Mycliophthora sepedonium</i>	-	-	1	2
<i>Microascus cirrosus</i>	2	4	2	4
<i>M. pyramidus</i>	-	-	3	6
<i>Penicillium chrysogenum</i>	7	14	8	16
<i>Phaeoacremonium</i> sp.	1	2	2	4
<i>Rhizopus stolonifer</i>	5	10	-	-
<i>Scopulariopsis brevicaulis</i>	2	4	-	-
<i>Sordaria lappae</i>	-	-	2	4
Sterile mycelium (White)	1	2	2	4
<i>Stachybotrys atra</i>	1	2	-	-
<i>Syncephalastrum racemosum</i>	2	4	-	-
<i>Trichoderma</i> sp.	2	4	-	-
Yeast	34	68	18	36

Aspergillus was the most common genus with eight species. *A. flavus*, *A. niger* and *A. versicolor* were detected from both dust sources. *A. japonicus*, *A. niveus* and *A. robustus* were detected at lower frequency from the mosques dust. Few species of black aspergilli were encountered from the indoor environment. However, *A. niger* was the most detected species. *A. japonicus* is rarely encountered. Our finding is in consistent with previous reports (Bokhary, 1999; Maghraby et al., 2008; Varga et al., 2014; Visagie et al., 2014a).

Three entomopathogenic fungi were detected of which *B. bassiana* at rates of 8 and 16%, *P. lilacinum* at 6 and 2% were from houses and mosques dusts, respectively. *M. anisopliae* was detected at 10% frequency from house dust only.

Several specific media that contained antifungal and antibiotic agents at appropriate concentration that inhibit rapidly growing saprophytic fungi and allow the growing of target fungi were developed (Goettel & Inglis, 1997; Luz et al., 2007; Fernandes et al., 2010; Abdullah et al., 2015b; Kepler et al., 2015). In the present study, we used a selective medium based on CTAB at 0.6 g/l and oat meal agar as a basal medium as described by Pasudos et al. (2012) and modified by addition of cycloheximide 0.5 g/l.

Entomopathogenic fungi of the genera *Beauveria* and *Metarhizium* (Hypocreales: Ascomycetes) are widely used in biological control against a broad spectrum of pest insects (De Faria & Wraight, 2007). Although soil is the main natural habitat for entomopathogenic fungi, there are increased evidences for their occurrence as endophytes (Arnold & Lewis, 2005; Steinwender et al., 2015) and rarely encountered from dust (Maghraby et al., 2008). We successfully detected three entomopathogenic fungi from dusts of houses and mosques.

Although entomopathogenic fungi are well known as insect pathogens. However, few reports documented their pathogenic potential towards humans. *M. anisopliae* can manifest as agents of keratitis (De Garcia et al., 1997; Jani et al., 2001) and disseminated skin lesions (Osorio et al., 2007). Ocular infections caused by *Beauveria bassiana* have been also reported (Low et al., 1997; Kisla et al., 2000). Two species of *Chaetomium* (*C. longicolleum* and *C. madrasens*) were detected from mosque dust at isolation frequency of 4 and 2%, respectively. The two species have been recently reported from Iraqi soil (Abdullah & Azzo, 2015).

Phaeoacremonium sp. was detected in dust sample from houses and mosques at frequency of 2 and 4%, respectively. *Phaeoacremonium* species have been previously reported from Iraq as among the other fungi causing grapevine decline in Iraq (Haleem et al., 2011; Abdullah et al., 2015a).

Phaeoacremonium species are among other dematiaceous hyphomycetes reported as etiologic agent of cutaneous and subcutaneous phaeohyphomycosis (Mostert et al., 2005; Marques et al., 2006).

Other species were isolated at different frequency including *Acaulium*, *Alternaria*, *Fusarium* sp., *Stachybotrys atra* and *Syncephalastrum racemosus*, yeast and sterile mycelium. Most of those above species have been isolated from indoor dusts by several studies (Bahkali & Parvez, 1999; Abdullah & Al-Musa, 2000; Maghraby et al., 2008; Singh et al., 2009; Al-Humiany, 2010; Abdullah & Al-Musa, 2011; Yasser, 2013).

Conclusions

Carpet dusts in residential houses and mosques are rich in diverse types of fungi including dermatophytes, related keratinophilic fungi, entomopathogenic fungi and cycloheximide resistant fungi. Most of the recovered species during this investigation can be considered as potential pathogens to humans. Some of the recovered species, particularly in the genera *Aspergillus*, *Penicillium*, *Fusarium* and *Stachybotrys*, are well known as mycotoxins producers.

References

- Abdullah, S.K. & Al-Musa, A.A. (2000). The incidence of keratinophilic and actidione resistance fungi in the floor dust of residential houses in Basrah. *Basrah J. Sci.*, B. 18 (1): 45-54.
- Abdullah, S.K. & Al-Musa, A.A. (2011). Isolation of keratinophilic and actidione resistant fungi in the floor dust of mosques in Basrah, Iraq. 2nd Sci. Conf. Biol. Sci., Mosul Univ., Iraq: 58-69.
- Abdullah, S.K. & Azzo, N.M. (2015). Two new records of *Chaetomium* species isolated from soil under grapevine plantations and a checklist of the genus in Iraq. *J. Agric. Technol.*, 11 (7): 1515-1522.
- Abdullah, S.K.; Al-Samarraie, M.Q. & Al-Assie, A.H. (2015a). Fungi associated with grapevine (*Vitis vinifera* L.) decline in middle of Iraq. *Egypt. Acad. J. Biol. Sci.*, 7 (1): 53-59.
- Abdullah, S.K.; Mustafa, R.A. & Assaf, L.H. (2015b). Isolation of entomopathogenic and opportunistic fungi from soil in Duhok province, Kurdistan region of Iraq by different selective isolation media. *J. Biol., Agric. Healthcare*, 5 (4): 73-79.
- Al-Humiany, A.A. (2010). Opportunistic pathogenic fungi of the house dust in Turubah, Kingdom of Saudi Arabia. *Aust. J. Basic Appl. Sci.*, 4 (2): 122-126.
- Al-Musa, A.A. & Abdullah, S.K. (2001). Prevalence of keratinophilic and opportunistic fungi in the floor dust of some hotels in Basrah, Iraq. *J. Basrah Res.*, 27: 69-81.

- Arnold, A.E & Lewis, L.C. (2005). Ecology and evolution of fungal endophytes, and their roles against insects. In: Vega, F.E. & Blackwell, M. (eds.). Insect-fungal associations: Ecology and evolution. Oxford Univ. Press: 74-96.
- Bahkali, A.H. & Parvez, S. (1999). Fungal flora in house dust in Riyadh, Saudi Arabia. *Mycoses*, 42 (4): 339-343.
- Beguín, H. & Nolard, N. (1996). Prevalence of fungi in carpeted floor environment: Analysis of dust samples from living rooms, bedrooms, offices and school classrooms. *Aerobiologia*, 12 (2): 113-120.
- Bischoff, J.F.; Rehner, S.A. & Humber, R.A. (2009). A multilocus phylogeny of the *Metarhizium anisopliae* lineage. *Mycologia*, 101: 512-530.
- Bokhary, H.A. (1999). Osmotolerant and osmophilic fungi from home dust. Riyadh, Saudi Arabia. *Saudi. J. Biol. Sci.*, 6 (2): 147-155.
- Currah, R.S. (1985). Taxonomy of the Onygenales: Arthrodermataceae, Gymnoascaceae, Myxotrichaceae and Onygenaceae. *Mycotaxon.*, 24: 1-216.
- De Ana, S.G.; Torres-rodriguez, J. M.; Rumirez, E.A.; Garcia, S.M. & Belmonte-Soler, J. (2006). Seasonal distribution of *Alternaria*, *Aspergillus*, *Cladosporium* and *Penicillium* species isolated in houses of fungal allergic patients. *J. Investig. Allergol. Clin. Immunol.*, 16: 357-363.
- De Faria, M.R & Wraight, S.P. (2007). Myco- insecticides and myco- acaricides: A comprehensive list with worldwide coverage and international classification of formulation types. *Biol. Control*, 43: 237-256.
- De Garcia, M.C.; Arbotoda, M.I.; Barraquer, F. & Grose, E. (1997). Fungal keratitis caused by *Metarhizium anisopliae* var. *anisopliae*. *J. Med. Vet. Mycol.*, 35: 361-363.
- De Hoog, G.S. & Guarro, J. (1995). Atlas of clinical fungi. Centraalbureau voor Schimmelcultures, the Netherlands and Universitat Rovira in Virgili, Spain: 720 pp.
- Domsch, K.H.; Games, W. & Anderson, T.H. (1980). Compendium of soil fungi. Acad. Press., London: 860 pp.
- Ellis, M.B. (1971). Dematiaceous hyphomycetes. Commonwealth Mycological Institute, Kew Surrey: 608 pp.
- Ellis, M.B. (1976). More dematiaceous hyphomycetes. Commonwealth Mycological Institute, Kew, Surrey: 507 pp.
- Engelhart, S.; Look, A.; Skutlarek, D.; Sagunski, H.; Lommel, A.; Farher, H. & Exner, M. (2002). Occurrence of toxigenic *Aspergillus versicolor* isolates and sterigmatocystin in carpet dust from damp indoor environment. *Appl. Environ. Microbiol.*, 68: 3886-3890.
- Fernandes, E.K.K.; Keyser, C.A.; Rangel, D.E.N.; Eoster, R.N. & Roberts, D.W. (2010). CTC medium: A novel dodine-free selective medium for isolating entomopathogenic fungi, especially *Metarhizium acridum*. *Biol. Control*, 54 (3): 197-205.
- Goettel, M. & Inglis, D. (1997). Fungi: Hyphomycetes. In: Lacy, L. (ed.). Manual of techniques in insect pathology. Acad. Press, Amsterdam: 213-249.
- Guarro, J.; Gene, J.; Stchigel, A.M. & Figueras, M.J. (2012). Atlas of soil ascomycetes, CBS Biodiversity Series. Fungal Biodiversity Center, Utrecht, the Netherlands: 485 pp.
- Haleem, R.A.; Abdullah, S.K. & Jubraeel, J.M.S. (2011). Morphological and molecular identification of *Phaeoacremonium aleophilum* associated with grapevine decline phenomena in Duhok governorate. *J. Basrah Res. (Sci.)*. 37 (4E): 1-8.
- Jaakkola, M.S.; Laitinen, S.; Piipari, R.; Uitti, J.; Nordman, H.; Hoopula, A.M. & Jaakkoh, J.J. (2002). Immunoglobulin G antibodies against indoor dampness- based microbes and adult-onset asthma: A population based incident case-control study. *Clin. Exp. Immunol.*, 129: 107-112.

- Jacobs, R.L. & Andrew, C.P. (2003). Hypersensitivity pneumonia-nonspecific interstitial pneumonia fibrosis histopathologic presentations: A study in diagnosis and long term management. *Ann. Aller. Asthma. Immunol.*, 90 (2): 265-270.
- Jani, B.R.; Rinaldi, M.G. & Reinhart, W.J. (2001). An unusual case of fungal keratitis: *Metarhizium anisopliae*. *Cornea*, 20: 765-768.
- Kawel, N.; Schorer, G.; Desbiolles, I.; Seiferet, B.; Marincek, B. & Boehm, T. (2011). Discrimination between invasive pulmonary aspergillosis and pulmonary lymphoma using CT. *Eur. J. Radiol.*, 77 (3): 417-425.
- Kepler, R.M.; Ugin, T.A.; Maul, J.E.; Cavigelli, M.A. & Rehner, S.A. (2015). Community composition and population genetic of insect pathogenic fungi in the genus *Metarhizium* from soils of a long term agricultural research system. *Environ. Microbiol.*, 17: 2791-2804.
- Kidd, S.; Haliday, C.; Alexiou, H. & Ellis, D. (2016). Descriptions of medical fungi, 3rd edition, New Style Printing, Adelaide, Australia: 266 pp.
- Kisla, T.A.; Cu-Unjieng, A.; Sigler, L. & Sugar, J. (2000). Medical management of *Beauveria bassiana* keratitis. *Cornea*, 19: 405-406.
- Klich, M.A. (2002). Identification of common *Aspergillus* species. CBS. Utrecht. The Netherlands: 116 pp.
- Low, C.D.; Badenoch, P.R. & Coster, D.J. (1997). *Beauveria bassiana* keratitis cured by deep lamellar dissection. *Cornea*, 16: 698-699.
- Luz, C.; Tai, M.H.H.; Santos, A.H.; Rocha, L.F.N.; Albernaz, D.A.S. & Silva, H.H.G. (2007). Ovicidal activity of entomopathogenic hyphomycetes on *Aedes aegypti* (Diptera: Culicidae) under laboratory conditions. *J. Med. Entomol.*, 44: 799-804.
- Maghraby, T.A.; Gherbawy, Y.A.M.H. & Hussein M.A. (2008). Keratinophilic fungi inhabiting floor dusts of student houses at the South Valley University in Egypt. *Aerobiologia*, 24: 99-106.
- Marques, S.A.; Camargo, R.P.M.; Summerbell, R.C.; Hoog, G.S.; Ishioka, P.; Chambo-Cordarô, L.M. & Marques, M.E.A. (2006). Subcutaneous phaeohyphomycosis caused by *Phaeoacremonium parasiticum* in a renal transparent patient. *Med. Mycol.*, 44 (7): 671-676.
- Mostert, L.; Groeneveld, J.Z.; Summerbell, R.C.; Robert, V.; Sulton, D.A.; Padhye, A.A. & Crous, P.W. (2005). Species of *Phaeoacremonium* associated with infections in human and environmental reservoirs in infected woody plants *J. Clin. Microbiol.*, 43 (4): 752-767.
- Nevalainen, A. & Seuri, M. (2005). Of microbes and men. *Indoor Air*, 15 (Suppl. 9): 58-64.
- Oorschot, van, C.A.N. (1980). A revision of *Chrysosporium* and allied genera. *Stud. Mycol.*, 20: 1-89.
- Osorio, S.; de La Camara, R.; Monteserin, M.C.; Grunados, R.; Ona, F.; Rodriguez-Tudela, J.L. & Cuenea-Esterlla, M. (2007). Recurrent disseminated skin lesions due to *Metarhizium anisopliae* in an adult patient with acute myelogenous leukemia. *J. Clin. Microbiol.*, 45 (2): 651-655.
- Pasudos, J.B.; Comerrio, R.M.; Mrni, J.I.; Nussenbanuru, A.L. & Lecuona, R.E. (2012). A novel-dodine free selective medium based on the use of cetyltrimethyl ammonium bromide (CTAB) to isolate *Beuaveria bassiana*, *Metarhizium anisopliae sensu lato* and *Paecilomyces lilacinus* from soil. *Mycologia*. 104 (4): 974-980.
- Pitt, J.I. & Hocking, A.D. (1997). Fungal and food spoilage. 2nd ed. Blackie Acad. Prof., London: 511 pp.
- Samson, R.A.; Hoekstra, E.S.; Frisvad, J.C. & Filtenborg, O. (2000). Introduction to food and air borne fungi, 6th ed. Central Bureau voor Schimmelcultures, Baarn, The Netherlands: 389 pp.

- Samson, R.A.; Noonim, P.; Meijer, M.; Houbraken, J.; Frisvad, J.C. & Varga, J. (2007). Diagnostic tools to identify black aspergilli. *Stud. Mycol.*, 59: 129-145.
- Sandoval-Denis, M.; Gené, J.; Sutton, D.A.; Cano-lira, J.F.; De Hoog, G.S.; Decock, C.A.; Wiederhod, N.P. & Guarro, J. (2016a). Redefining *Microascus*, *Scopulariopsis* and allied genera. *Persoonia*, 36: 1-36.
- Sandoval-Denis, M.; Guarro, J.; Cano-lira, J.F.; Sutton, D.A.; Wiederhod, N.P.; De Hoog, G.S.; Abbott, S.P.; Decock, C.; Sigler, L & Gene, J. (2016b). Phylogeny and taxonomic revision of Microascaceae with emphasis on synematosus fungi. *Stud. Mycol.*, 83: 193-233.
- Santillo, D.; Labunske, I.; Davizson, H.; Johnston, P.; Strutt, M. & Knowles, O. (2003). Consuming chemicals: Hazardous chemical in house dust as an indicator of chemical exposure in the home. Greenpeace Research Laboratories. Tech. Note 01/2003, Univ. Exeter, England: 69 pp.
- Singh, I.; Mishra, A. & Kushwaha, R.K.S. (2009). Dermatophytes, related keratinophilic and opportunistic fungi in indoor dust of houses and hospitals. *Ind. J. Med. Microbiol.*, 27 (3): 242-246.
- Skora, J.; Sutyok, M.; Nowak, A.; Otlewska, A. & Gutarowska, B. (2017). Toxinogenicity and cytotoxicity of *Alternaria*, *Aspergillus* and *Penicillium* molds isolated from working environments. *Int. J. Environ. Sci. Technol.*, 14: 595-608.
- Stark, P.C.; Celedon, J.C.; Chew, G.L.; Ryan, L.M.; Burge, H.A.; Muilenberg, M.L. & Gold, D.R. (2005). Fungal levels in the home and allergic rhinitis by 5 years of age. *Environ. Health Perspect.*, 113 (10): 1405-1409.
- Steinwender, B.M.; Enkerli, J.; Widmer, F.; Eilenberg, J.; Kristensen, H.L.; Bilochka, M.J. & Meyling, N.V. (2015). Root isolations of *Metarhizium* spp. from crops reflect diversity in the soil and indicate no plant specificity. *J. Invertebr. Pathol.*, 132: 142-148.
- Tzean, S.S.; Hsieh, L.S. & Wu, W.J. (1997). Atlas of entomopathogenic fungi from Taiwan. Council of Agriculture; Executive Yuan, Taipei, Taiwan: 214 pp.
- Varga, J.; Kocsube, S.; Szrgeti, G.; Baranyi, N.; Vagvolgyi, C.; Despot, D.J.; Magyar, D.; Meijer, M.; Samson, R.A. & Klaric, S. (2014). Occurrence of black aspergilli in indoor environment of six countries. *Arch. Hig Rada Toksikol.*, 65: 2. DOI: 10.2478/10004-1254-65-2014-2450.
- Visagie, C.M.; Hirooka, Y.; Tanney, J.B.; Whitfield, E.; Mwange, K.; Meijer, M.; Amend, A.S.; Seifert, K.A. & Samson, R.A. (2014a). *Aspergillus*, *Penicillium* and *Talaromyces* isolated from house dust samples collected around the world. *Stud. Mycol.*, 78: 63-139.
- Visagie, C.M.; Varga, J.; Houbraken, J.; Meijer, M.; Kocsube, S.; Yilmaz, N.; Fotedar, R.; Seifert, K.A.; Frisvad, J.C. & Samson, R.A. (2014b). Ochratoxin production and taxonomy of the yellow aspergilla (*Aspergillus* Section *Circumdati*). *Stud. Mycol.*, 7 (8): 1-61.
- Weitzman, I. & Summerbell, R.C. (1995). The dermatophytes. *Clin. Microbiol. Rev.*, 8: 240-259.
- Wu, F.S.; Wu, M.W.; Pierse, N.; Crane, J. & Siebers, R. (2012). Daily vacuuming of mattresses significantly reduces house dust mite allergens, bacterial endotoxin and fungal B-glucan. *J. Asthma*, 49: 139-143.
- Yasser, M.M. (2013). Keratinophilic fungi inhabiting student house at Benisuef Univ., Egypt. *Arch. Biomed. Sci.*, 1 (2): 20-30.