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MONITORING, CONTROLLING AND PREVENTION OF THE FUNGAL DETERIORATION OF TEXTILE ARTIFACTS IN THE MUSEUM OF JORDANIAN HERITAGE

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ABSTRACT

This study aims at monitoring, controlling and prevention the fungal deterioration of the museum textiles in the museum of Jordanian heritage as a case study. In this study valuable fungal deteriorated textile samples collected from different areas in the storage rooms and the display halls in the selected museum, were used for isolating fungi. Both of the plate method with the manual key and the direct observation method by SEM were used for identification of the fungi. The results show that the most dominant fungi isolated from tested samples belong to *Aspergillus, Penicillium, Chaetomium and Alternaria* species. The results show that all kinds of textile fibers in both storage room and display halls in the selected museum suffer from fungal attack. This study confirms that the textile collections are displayed and storied in very poor environmental conditions. This study established a strategy for controlling and prevention of the fungal deterioration problem on textile objects in the Museum of Jordanian Heritage and includes disinfection of the biodeteriorated textile objects, and then controlling the environmental conditions surrounding the objects in display showcases and storage cabinets. For disinfection of fungal deteriorated textiles with active fungal infestation the study suggested some fungicides that are safe for both textile objects and conservators.

KEYWORDS: Museum textile samples, fungal deterioration, isolation and identification of fungi, SEM, fungal species, disinfection, fungicides, controlling, prevention

INTRODUCTION

Museum textiles are extremely susceptible to damage from environmental factors such as humidity, dust, airborne pollutants, light, heat etc. (Abdel-Kareem, 2002, Garside, Wyeth, 2002, NPS, 2002, NPS, 1999, Landi, 1998, Museums & Galleries Commission, 1998, Timar-Balazsy, Eastop, 1998). There is no doubt that the most serious damages in textiles are caused by microorganisms such as bacteria, actinomycetes and fungi (Kowalik, 1980). Fungi are very often found in display and storage conditions of museums (Giuliani, Nugari, 1993). Fungal degradation is one of the highest risk factors for deterioration of historic textiles (Abdel-Kareem, Radwan, 2004). The deterioration by fungi seems to be a predominant feature in museums in many different countries in all over the world as the fungi are the most active microorganisms in the degradation of textiles in museums (Giuliani, Nugari, 1993). A summary from around the world of the fungi found on heritage objects to reveals many species in common. Four genera (*Alternaria, Aspergillus, Cladosporium, and Penicililum*) are found on all objects and in the air worldwide. This supports a common origin of the fungi contaminating heritage objects: coming from airborne conidia during fabrication or during use (Florian, 1997). The environmental factors, which influence conidial germination and the subsequent hyphal growth, are the same. These factors are many and they include water relationships, temperature, oxygen and carbon dioxide, pH, light and toxic characteristics of the substrate (Florian, 1997). It was reported that among the most suitable conditions for the growth of fungi are: temperature between 24-30 °C, RH of 65-80%, and pH slightly acid, i.e. about 5.5 (Kowalik, 1980). However it was reported the range of temperatures favourable for fungal growth is large. Dormant conditions for spores, waiting for the proper environment to re-emerge, can range from 0° to 70°C (Montegut, Indictor, Kostler, 1991).

Fungal deterioration of textile materials causes changes in their oxidation stage, degrees of polymerisation, and breakdown of molecular structure. In turn it results in loss of strength, extensibility, general durability, discoloration, and appearance (Vigo, 1980, Aranyank, 1995, Sagar, 1987, Greaves, McCarthy, 1991, Florian, 1993, Peacock, 1996). Molds excrete enzymes that allow them to digest organic materials altering and weakening those materials. In addition, many molds contain colored substances that can cause stains and spots on textiles and decrease the strength of the fabric. Mold can be dangerous to people and in some cases can pose a major health hazard (Merritt, 1993). Identifying the fungi species and the factors enhance their growth is essential step for the success in establishing a proper and an effective strategy for controlling and prevention of their growth on the textile collections in the museums. The fungal problem should be given special attention regarding textile protection, whether by the control of the physical conditions in the surrounding environment or by the treatment with biocides. Control of the environmental conditions is the best means of protecting fabrics. Museum of Jordanian heritage is consider to be the most important museum in Jordan, as it shows the evolutionary stages of various civilizations within time sequence. Its exhibitions present the story of mankind from its earliest stages to today. Textile is considered to be one of the most important collections in Museum of Jordanian heritage. Most of textiles in the Museum of Jordanian Heritage are natural organic substances. Hence these textiles are liable to deterioration. It is noticed that textile collections in the museum of Jordanian heritage are displayed and storied in inappropriate environmental conditions. These conditions are very different from standard international regulations concerning the environment required in storage rooms, display showcases, windows and halls. It is thought that these conditions may encourage the deterioration of textile objects by fungi. Although a few studies have been done for monitoring and controlling of airborne pollutants in the museum of Jordanian heritage (Al-Saad, Khasawneh, 2006), aesthetically unpleased, no published studies of the fungal deterioration on textile objects in the museum of Jordanian heritage have yet solved the problem, or have provided details of their nature or degradation factors. For this reason,

this study aims at the monitoring and controlling of the fungal deterioration of textiles in the museum of Jordanian heritage. This study will identify the micro-flora occurrence on the textile collections in the museum of Jordanian heritage. Investigate the factors causes the fungal growth on the textiles in the museum of Jordanian heritage. Finally this study aims to establish a strategy for controlling and prevention the fungal deterioration of textiles in the museum of Jordanian heritage.

EXPERIMENTAL

Isolation and identification of fungi in historical biodeteriorated textile samples

Both the traditional method and the direct method using SEM were used to identify fungi on various biodeteriorated textile samples obtained and collected from both the display halls and the storage rooms in the museum of Jordanian heritage. It was confirmed in previous studies that the selected methods are the best methods which can be used in identifying fungi in biodeteriorated historical textiles (Abdel-Kareem, Szostak-Kotowa, Barabasz, Paśmionka, Galus, 1997, Abdel-Kareem, Szostak-Kotowa, 1999).

Isolation and identification of fungi by using the traditional methods

For isolation the fungi from the collected biodeteriorated textile samples it was used method of the incubation of the biodeteriorated textile samples directly for growing the microorganisms in these samples on various media without sours of carbon. According to this method it will be possible to identify only specifically fungi strains which able to cause damage to the textile materials. However even if microorganisms are isolated by using media with source of carbon, it is very difficult to know which specific microbial strains cause damage to the textile materials. In other wards, we can say that these strains may belong to airborne microorganisms not to investigated textiles (Abdel-Kareem, Szostak-Kotowa, Barabasz, Paśmionka, Galus, 1997). The samples were washed with sterilized distilled water and were transferred by using sterilized tweezers and were put on 2 various media in Petri dishes. 1- Medium of Greathous, Klemme and Barker with disk of cellulose paper with cellulosic textile samples or with disk of pure 100% wool with protein textile samples. 2- Czapek-Dox agar modified without sugar and agar (Kowalik, 1980, Booth, 1971). These prepared cultures were incubated at 28 °C for three to four weeks {until growth of colonies was observed}. For purification and identification, the developed fungi were isolated in pure culture on slants of the appropriate media (Czapek dox agar and malt extract agar) (Booth, 1971). The identification of fungal species was performed according to standardized methods by consulting the appropriate manuals (Domsch, Gams, Anderson, 1980, Gilman, 1975, Raper, Fennell, 1965, Raper, Thom, 1949).

Direct identification of fungi on samples by SEM

Scanning Electron Microscope (SEM) Model Quanta 200 was applied to examine the surface morphology of the biodeteriorated textile samples in order to detect fungal growth and to identify the fungal strains, as well as to investigate the damage in the surface morphology of the biodeteriorated textile samples. The investigation was applied according to (Abdel-Kareem and Szostak-Kotowa, 1999). Very small parts of the biodeteriorated textile samples were attached to a metal stub then coated with gold layer of about 200Aº thick. Next the coated samples were investigated.

RESULTS AND DISCUSSION

Isolation and identification of fungi by using the traditional methods

Fungi isolated from various biodeteriorated cellulosic textile fabrics from both display and storage area, were shown in table 1. The results show that the number of identified isolated fungi is 23 species. All identified fungi belong to Deuteromycetys class (*Alternaria, Aspergillus* and *Penicillium*) and Ascomycetes class (*Chaetomium*). The most dominant fungi on cellulosic textile fabrics are *Alternaria alternate*, *Alternaria tenuissima*, *Aspergillus carbonarius*, *Aspergillus fumigatus*, *Aspergillus flavus*, *Aspergillus nidulans*,

Aspergillus niger, Aspergillus terrus, Aspergillus sp., Aspergillus sp., Aspergillus sp., Penicillium asperum, Penicillium citrinum, Penicillium cyclopium, Penicillium funiculosum, Penicillium soppi, Penicillium sp., Penicillium sp., Penicillium sp., Chaetomium cochlioides, Chaetomium globosum, Chaetomium sp., and *Chaetomium sp.* The results show that the total number of isolated fungi from the storage area is more than from the display area. It is noticed that the order of occurrence fungi on cellulosic textile fabrics in both display and storage area is as follows: *Aspergillus* > *Chaetomium* > *Penicillium* > *Alternaria*. Fungi isolated from various biodeteriorated protein textile fabrics from both display and storage area, were shown in table 2. The results show that the number of identified isolated fungi is 16 species. All identified fungi belong to Deuteromycetys class (*Alternaria, Aspergillus* and *Penicillium*) and Ascomycetes class (*Chaetomium*). The most dominant fungi on protein textile fabrics are *Alternaria alternate, Aspergillus flavus, Aspergillus fumigatus, Aspergillus nidulans, Aspergillus niger, Aspergillus wentii, Aspergillus sp., Aspergillus sp., Penicillium cyclopium, Penicillium paxilli, Penicillium sp., Penicillium sp., Chaetomium cochlioides, Chaetomium globosum, Chaetomium sp.,* and *Chaetomium sp.* The results show that the total number of isolated fungi from the storage area is more than from the display area. It is noticed that the order of occurrence fungi on cellulosic textile fabrics in both display and storage area is as follows: *Aspergillus* > *Chaetomium* > *Penicillium* > *Alternaria*. From the numbers of isolated fungi it is clear that textile collections in the Museum of Jordanian Heritage suffer from an excessive fungal infestation as there are about 25 fungi species were identified (see table 3). The results show that cellulosic textile fabrics in both display and storage area in the Museum of Jordanian Heritage, are more liable to fungal deterioration than protein textile fabrics (see table 3). These results are in agreement with the results obtained by Abdel-Kareem, et al, 1997, who confirmed that all types of ancient Egyptian textile fibers are liable to fungal attack; cellulosic fibers are more liable than animal fibers. This is due to that the improper methods used for display and storage of textiles in both Egypt and Jordan.

Table 1 Isolated fungi from various tested bio-deteriorated cellulosic textile samples

Fungi		Number of isolations	
		Display	Storage
1	*Alternaria alternate* (Fr.) Keissl	3	5
2	*Alternaria tenuissima* Kunze	2	4
3	*Aspergillus carbonarius* Bainier	3	5
4	*Aspergillus flavus* Link	8	11
5	*Aspergillus fumigatus* Fresenius	9	13
6	*Aspergillus nidulans* Eidam	6	8
7	*Aspergillus niger* Tieghem	9	12
8	*Aspergillus terrus* Thom	6	10
9	*Aspergillus sp.*	7	10
10	*Aspergillus sp.*	5	7
11	*Aspergillus sp.*	4	6
12	*Penicillium asperum* (Shear) n.comb.	2	4
13	*Penicillium citrinum* Thom	5	7
14	*Penicillium cyclopium* Westling	3	5
15	*Penicillium funiculosum* Thom	6	8
16	*Penicillium soppi* Zaleski	3	5
17	*Penicillium sp.*	3	4
18	*Penicillium sp.*	2	3
19	*Penicillium sp.*	2	3
20	*Chaetomium cochlioides* Palliser	8	10
21	*Chaetomium globosum* Kunze	10	13
22	*Chaetomium sp.*	5	8
23	*Chaetomium sp.*	4	7

Table 2 Isolated fungi from various tested bio-deteriorated protein textile samples

Fungi		Number of isolations	
		Display	Storage
1	*Alternaria alternate* (Fr.) Keissl	2	4
2	*Aspergillus flavus* Link	4	6
3	*Aspergillus fumigatus* Fresenius	7	9
4	*Aspergillus nidulans* Eidam	3	5
5	*Aspergillus niger* Tieghem	5	8
6	*Aspergillus wentii* Wehmer	2	4
7	*Aspergillus sp.*	4	6
8	*Aspergillus sp.*	3	5
9	*Penicillium cyclopium* Westling	3	4
10	*Penicillium paxilli* Bainier	2	3
11	*Penicillium sp.*	2	4
12	*Penicillium sp.*	2	3
13	*Chaetomium cochlioides* Palliser	6	9
14	*Chaetomium globosum* Kunze	7	10
15	*Chaetomium sp.*	5	8
16	*Chaetomium sp.*	4	7

Table 3 Isolated fungi from various tested biodeteriorated textile samples

Fungi		Cellulosic	Protein
1	*Alternaria alternate* (Fr.) Keissl	+	+
2	*Alternaria tenuissima* Kunze	+	-
3	*Aspergillus carbonarius* Bainier	+	-
4	*Aspergillus flavus* Link	+	+
5	*Aspergillus fumigatus* Fresenius	+	+
6	*Aspergillus nidulans* Eidam	+	+
7	*Aspergillus niger* Tieghem	+	+
8	*Aspergillus wentii* Wehmer	-	+
9	*Aspergillus terrus* Thom	+	+
10	*Aspergillus sp.*	+	+
11	*Aspergillus sp.*	+	+
12	*Aspergillus sp.*	+	-
13	*Penicillium asperum* (Shear) n.comb.	+	-
14	*Penicillium citrinum* Thom	+	-
15	*Penicillium cyclopium* Westling	+	+
16	*Penicillium funiculosum* Thom	+	-
17	*Penicillium paxilli* Bainier	-	+
18	*Penicillium soppi* Zaleski	+	-
19	*Penicillium sp.*	+	+
20	*Penicillium sp.*	+	+
21	*Penicillium sp.*	+	-
22	*Chaetomium cochlioides* Palliser	+	+
23	*Chaetomium globosum* Kunze	+	+
24	*Chaetomium sp.*	+	+
25	*Chaetomium sp.*	+	+

Direct identification of fungi on samples by SEM

The results of investigation of the biodeteriorated textile samples using SEM show that the most dominant fungi on both cellulosic and protein textile fabrics in both display and storage area are *Aspergillus*, *Chaetomium* and *Penicillium* species. It is noticed that species of *Aspergillus* formed well developed vegetative mycelia and conidial apparatus (conidiophores). Aspergillus is characterized by the head-like termination of the conidiophores. The conidial heads can be observed, as the conidiophore grows directly from the substrate or from aerial hyphae (see figure 1). However the results show that it is only to identify Aspergillus as a class only but the classification of species of Aspergillus directly, is difficult.

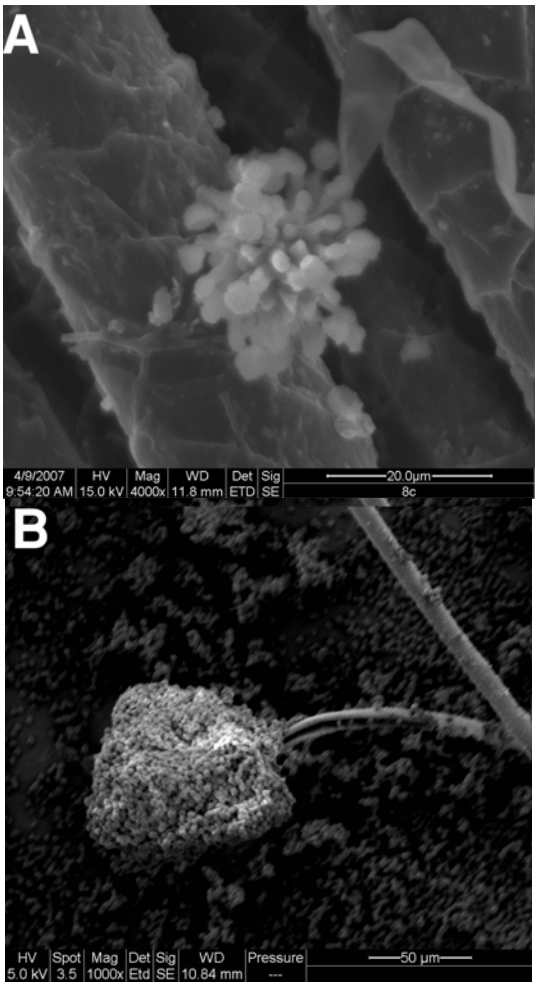

Figure 1 SEM. photographs of conidiophores and conidia *of Aspergillus sp.* on biodeteriorated textile samples A) Protein fibers B) Cellulosic fibers

Species of *Chaetomium* are abundant on investigated biodeteriorated textiles. It is observed that species of *Chaetomium* typically produce perithecia on the surface of the hyphal mat. Perithecia are spherical, subglobose, elongated or vase-shaped. The mycelium consists of sparsely or densely branching fungus threads radiating in a network from the point of origin. The terminal hairs arise from the region of the neck around the ostiole. The ascospores are ovate or roughly egg-shaped (see figure 2). However the results show that it is only to identify *Chaetomium* as a class only but the classification of species of *Chaetomium* directly, is difficult. But the results show that *Chaetomium globosom* may abundant as the ascospores are ovate or roughly egg-shaped that characterized *Chaetomium globosom* (Abdel-Kareem and Szostak-Kotowa, 1999).

It is observed the conidial heads and ascospores of different species of *Penicillium* are evident (see figure 3). Species of *Penicillium* are characterized by the colony consists of a straight, aerial, septate, stalk-hypha branching above and finally producing a group of parallel terminal spore-forming cells (phialides). Each of these gives rise to a chain of conidia (phialospores). However the results show that it is only to identify *Penicillium* as a class only but the classification of species of *Penicillium* directly, is difficult.

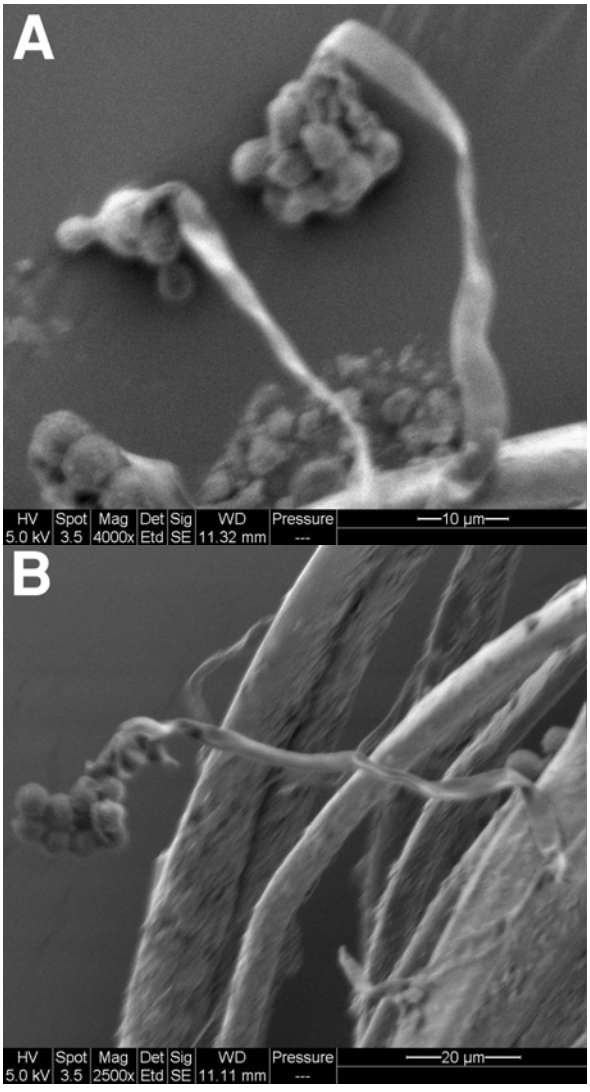

Figure 2 SEM. photographs of Perithecium, terminal hairs and ascospores of *Chaetomium sp.* on biodeteriorated textile samples A) Protein fibers B) Cellulosic fibers

S.E.M. photographs of biodeteriorated surfaces of the investigated textile samples were presented in figures 4-6. The results show that the surfaces were covered with fungal mycelia and conidial heads, and the attacked surfaces were rough and characterised by small scratches, large slits and holes. It could be seen in that the fungal mycelia and spores were readily observed, and that the attacked and roughened surface were clearly distinguished from the surface without fungal growth. Since the fungal mycelia made holes, fungi clearly grew not only on the surface but also within the fibers. When considering the S.E.M. photographs of the investigated biodeteriorated textile samples figures 4-6, we observed that the scanning electron microscope is very useful for identification of fungal groups that grow on biodeteriorated textiles directly and also investigation and assessing the deterioration extent in the surface of investigated textile samples.

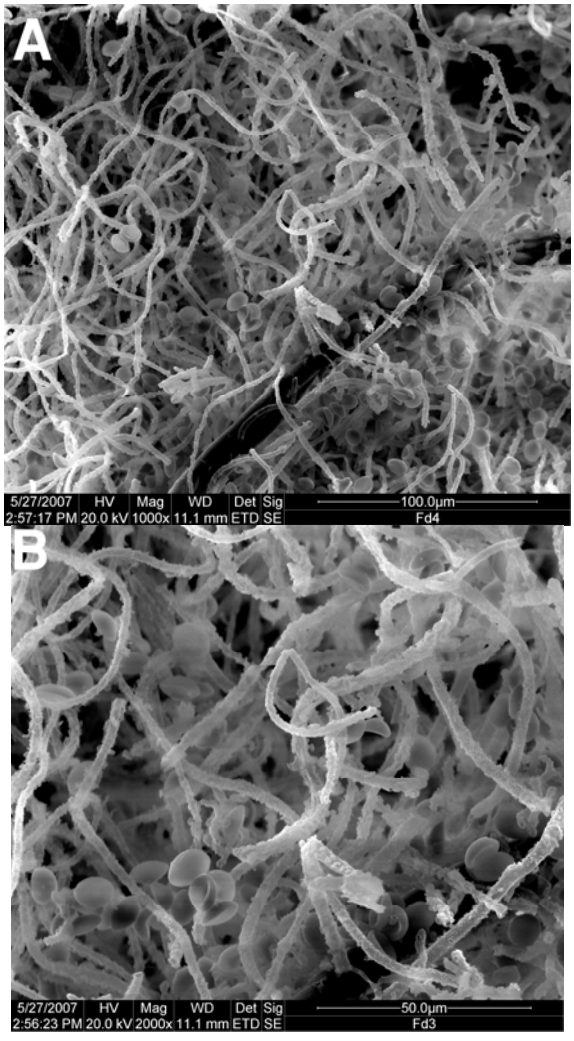

Figure 3 SEM. photographs of Conidiophores and conidia of *Penicillium sp.* on biodeteriorated textile samples A) Protein fibers B) Cellulosic fibers

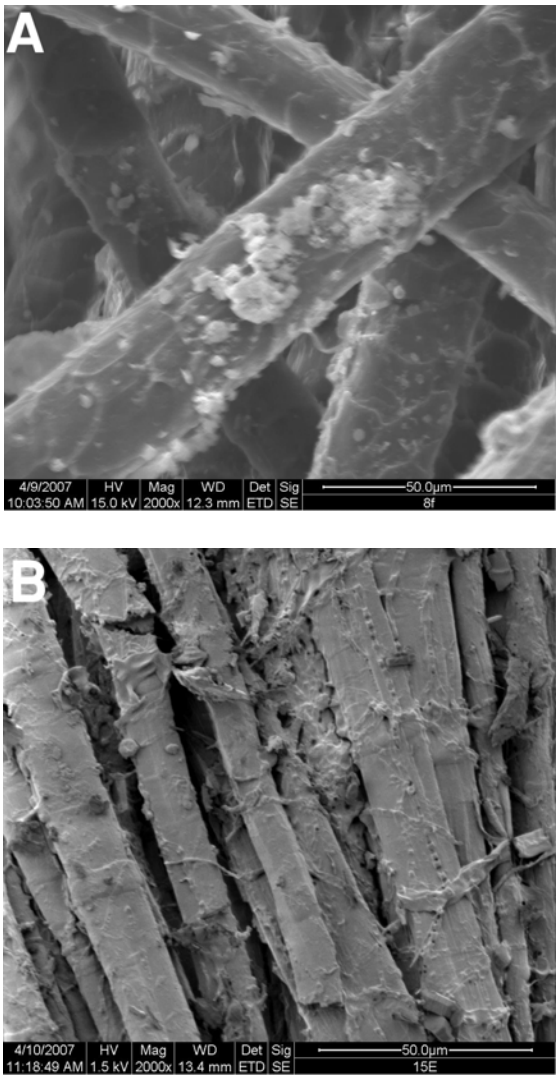

Figure 4 SEM photographs of the biodeteriorated surface of cellulosic and protein textile samples infested with *Aspergillus sp*. A) Protein fibers B) Cellulosic fibers

These results are in agreement with the results obtained with Abdel-Kareem and Szostak-Kotowa 2003, who confirmed that scanning electron microscope is a useful, quick and easy tool, to identify fungal deterioration on historical textiles that can be apply by all conservators without any difficulties (Abdel-Kareem and Szostak-Kotowa, 1999).

CONTROLLING AND PREVENTION OF FUNGAL DETERIORATION ON TEXTILE COLLECTIONS IN THE MUSEUM OF JORDANIAN HERITAGE

The success in controlling and prevention of fungal deterioration of textile collections in any museum can be achieved by monitoring, eliminating and controlling the fungal deterioration factors. So that the strategy suggested for controlling and prevention of the fungal deterioration in the current museum includes the following steps; (1) Monitoring the factors and the causes that led to the fungal deterioration of these textile objects. (2) Decontamination of fungi, this step includes the removal of the conidia and mycelium from biodeteriorated textile objects using methods not harmful to textile objects. (3) Disinfections the fungal growths using a suitable method. (4) Establishing guidelines for controlling and prevention of fungal deterioration of textile while their display or storage in the museum.

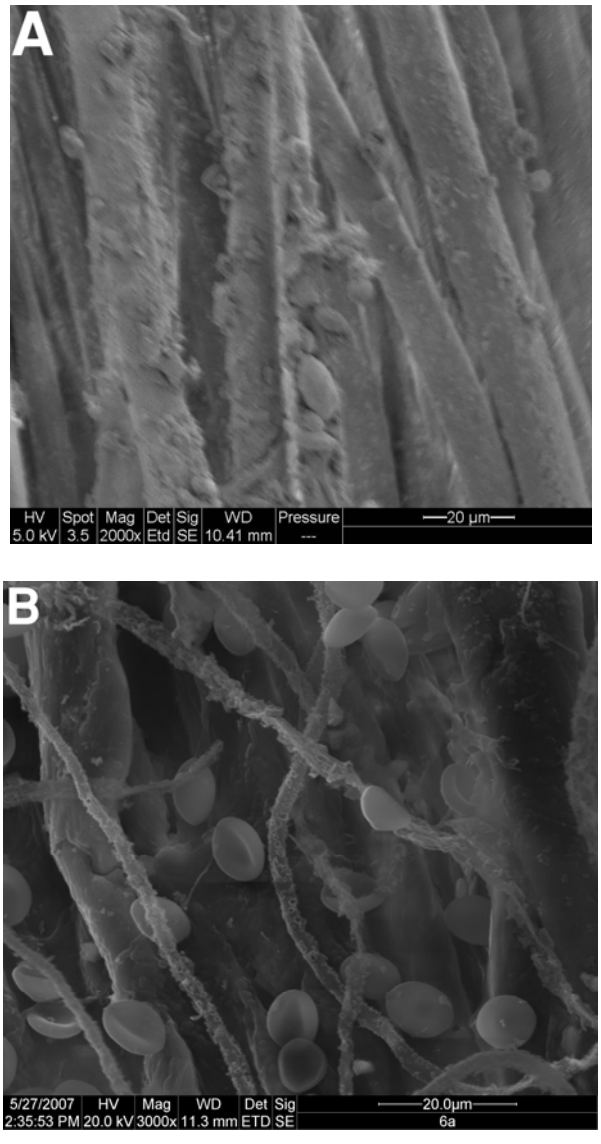

Figure 5 SEM photographs of the biodeteriorated surface of cellulosic and protein textile samples infested with *Chaetomium sp*. A) Protein fibers B) Cellulosic fibers

Monitoring the causes that led to the fungal deterioration of textile objects in the Museum of Jordanian Heritage

The obtained results show that there are serious excessive fungal infestations on all investigated textile objects especially those obtained from the storage area. The results show that the most of identified fungi are conidial fungi. These results indicate that the fungal infestations in the Museum of Jordanian Heritage may due to very poor environmental conditions used in display or storage of textile collection in the museum. By observation the building constructions of the museum, existing display showcases and structure and organization of the store rooms, it is clear that the museum conditions promote the fungal growth on textile collections. The store rooms of the museum are situated in the basement of the Faculty of Religious Studies on the Yarmouk University campus.

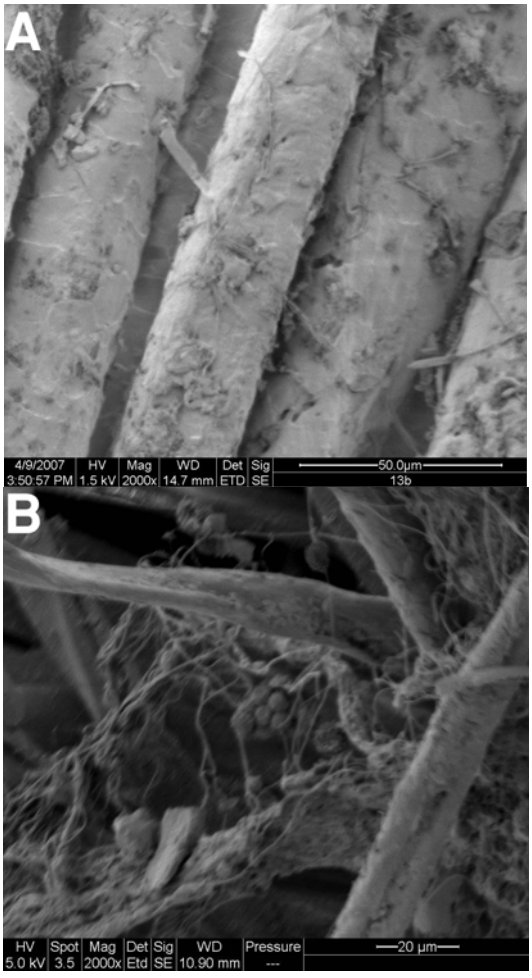

Figure 6 SEM photographs of the biodeteriorated surface of cellulosic and protein textile samples infested with *Penicillium sp*. A) Protein fibers B) Cellulosic fibers

It is obvious that inappropriate materials and methods used in the storage of textiles in very pad environmental conditions which are far from the minimal standard regulations for storage of textiles. The structural walls of the museum are integrated as near walls of the showcases making the artefacts susceptible to variations in temperature and relative humidity from outside. The textile collections displayed in open display cases and closed display showcases. Since the construction of these showcases is not airtight, there is no separate controllable climate within the display showcases. Also materials such as wood, fabrics, cardboard and padding materials used in construction of showcases are inappropriate materials which characterized with heavy dusted and contaminated materials. The particulate pollutants are very noticeable inside the museum of Jordanian Heritage. Visible dirt such as smoked cigarettes inside the display area, garbage thrown from the upper floor into the museum courtyard, pigeon droppings and unsuitable deposit of building maintenance equipment within the exhibition space are threatening the museum environment. These results are in agreement with the results obtained with Al-Saad and Khasawneh who confirmed there are excessive various types of particulate pollutants in the Museum of Jordanian Heritage. These results indicate that the source of fungal contaminations of textile collections may due to the particulate pollutants as it is confirmed in previous studies that the particulate pollutants can be a source of contamination of textile objects with fungi [(Florian, 2004). It is noticed too that the environmental conditions in display and storage area promote the fungal growth as it is confirmed in previous studies that the relative humidity surrounding textile objects in Museum of Jordanian Heritage is about 78% with fluctuations of about 28% throughout the year. Also there are different types of pollution sources in the museum (Al-Saad, Khasawneh, 2006). This is due to the minimal climate control within the museum and the buildings insufficient insulation. This is because of that the Museum of Jordanian Heritage has no climate control facilities such as air-conditioning or a ventilation system. The existing electric heating system inside the

display area on the ground floor is broken and air circulation is produced through opening windows in the atrium. Therefore, the museum's climate depends highly on the exterior climate and weather conditions. So that it is observable that the inside museum climate is dependant on and equivalent to the outside climate.

Decontamination Conidia and Mycelium

Most of the identified fungi on investigated textile objects belong to Deuteromycetys fungi. These fungi are called imperfect or conidial fungi because their growth is initiated by conidia (Abdel-Kareem, Szostak-Kotowa, Barabasz, Paśmionka, Galus, 1997, Florian, 2004). The life cycle of the conidial fungi starts with a conidium that germinates and produces a vegetative stage on which are produced hundred of new conidia, which completes the cycle. The basis unit of vegetative growth of a fungus is the hyphae. A group or mass of hyphae is called mycelium (Florian, 1997). Fungal spores, hyphae and conidia can be carried and transferred by air from a biodeteriorated textile object to settle on a surface of another object causing a new fungal infestation (Florian, 2004). For all previous causes there is a necessity to decontaminate the biodeteriorated textile objects from conidia and mycelium in order to reduce the fungal growth on these textile objects and prevention of contamination other objects. For that the surface of the biodeteriorated textile objects should be vacuumed cleaning to remove mycelium and conidia. The vacuum cleaning method chosen should be acceptable by conservation standards to protect the integrity of the textile object. We can not hope to eliminate completely all conidia, but this is not necessary. The main goal of this process is to reduce the fungal load to the minimal level of the infestation and prevent recontamination (Florian, 2004). Vacuum cleaning method should be applied at low suction power, and through a gauze sheet or fin netting fabric placed over the textile object in order to not disturb loose fibers (Museums & Galleries Commission, 1998). Cleaning should be carried only by appropriately trained and supervised conservators, because unregulated suction can be dangerous which can cause picking up the object by holding it against the nozzle (Landi, 1998).

Disinfection

There are various methods and techniques can be used for killing and eradication of fungi such as freezing, heat treatment, chemicals, altered atmospheric gases and radiation (Florian, 1997). From theoretical point of view it is true that these methods are very good and effective. But from a textile conservator of view not all these methods can be applied in field of textile conservation in the Jordanian museums for some disadvantage of their use or because their high cost. It is often emphasised that the best method to prevent fungal growth is to protect surfaces from contamination, control moisture in materials and relative humidity (RH) to prevent growth and avoid treatments which may activate conidia (Florian, 1997). Although that the most common and least intrusive method for prevention of fungal growth is the control of the environment, in developing countries such as Jordan and elsewhere, such control is not always feasible. There is a lack in the financial support and lack in the facilities equipments which can be used for eradication of fungi in the Museum of Jordanian Heritage using nonchemical methods. Also this study showed that the surfaces of the tested textile objects were become contaminated and biodeteriorated by fungi. Moreover, Jordan is one of countries where fungal infection is common and that now is not able to control the biodeterioration by air-conditioning. Most of Jordanian museums have not been designed for this role. Control of the biodeterioration by air-conditioning is expensive and it requires extensive funding to build new museums or introduce some changes in the existing ones. According to all previous in such case, chemical fungicides could be considered as means of emergency treatment of active fungal growth, as well as used for prevention on objects at risk (Abdel-Kareem, 2000). It is confirmed in previous studies that if there are active fungal infestation and in extreme cases such as in our case study, a fungicide may have to be used (Florian, 2004). And there is then a need for emergency treatment against active fungal growth. Previous studies showed that

for protection of cellulosic textile fabrics against fungal deterioration there are a number of fungicides such which can be used with 1% concentrate to prevent the fungal growth completely (Abdel-Kareem, Radwan, 2004, Abdel-Kareem, 2000, Abdel-Kareem, Morsy, 2004). However they confirmed that the use of fungicides have to be the last choice may be carried out historical textiles if there are no any other solution better than them can be applied. As it is known that the previous fungicides are good in prevention of fungi but there is no information enough about the effect of these fungicides on dyed wool textiles; so the effect of the selected fungicides on dyed wool textiles have to be investigated in the future studies.

However remedial treatments using fungicides to eliminate fungi should be minimal, in order to reduce the potential risk of damage to textile objects, the environment, to the museum staff and visitors. Very specific regulations control the use of biocides in museums, and COSHH regulations should be applied (Museums & Galleries Commission, 1998). A suggested fungicide should meet the following criteria and requirements, although it is accepted that not all these criteria can be ever entirely met (Abdel-Kareem, 2000). It must be toxic to a wide range of organisms or should block their action. It must not decrease mechanical properties of textiles as tensile strength, elongation, tear strength, flexibility, etc. It must not accelerate ageing of the textile materials nor causes any fading of dyes. It must not give off damaging products on decomposition. It must not cause yellowness or darkness of textiles. It must not cause changes in the chemical composition of textiles. It must not be toxic to human beings. It must be resistant to leaching. From the previous studies we can recommend one of the following fungicides to be used for disinfection of the biodeteriorated textiles in the Museum of Jordanian Heritage; Dichlorophene, Irgasan DP-300, Preventol O-Na, Preventol R-80 or Lichenicidia (Abdel-Kareem, Radwan, Abdel-Kareem, Morsy, 2004). Some tests should be done to choose the fungicide that does not cause bleeding to the dyes on the treated textiles. For example for textiles with dyes not sensitive to water it is recommended Preventol O-Na as it can be dissolved in distilled water, while for textile with dyes not sensitive to ethyl alcohol it is recommended Preventol R-80. However other studies should be carried to investigate the long term effect of the selected fungicides on the other properties of dyed textiles which did not investigate in the previous studies.

Suggested guidelines for controlling and prevention of the fungal deterioration on the textile collections in the Museum of Jordanian Heritage while their display and storage

Prevention includes protecting the textile objects from the contamination by fungi and controlling the environment conditions in the display show cases and storage rooms to prevent the development and the growth of fungi (Florian, 1997, Florian, 2004). The most and the least intrusive method for protection of textile objects from fungal infestations in museums, can be can be achieved by controlling the environmental conditions surrounding textile objects (Abdel-Kareem, Radwan, Abdel-Kareem, 2000, Abdel-Kareem, Morsy, 2004). Since "unsuitable environmental conditions are a serious cause of decay" a focus of the museum's management should lie on the establishment of appropriate environmental conditions for the textile objects. Naturally the implementation of a preventive conservation plan involves financial supports that are not enough in the university for this purpose. Therefore, not all of the standard regulations which we wish to be used for controlling and prevention of the fungal deterioration in the museum are feasible; nevertheless it would be desirable and advisable to at least consider the low cost improvements for immediate implementation.

The following consideration should be undertaken; Elimination/ prevention of airborne fungi using the considerations mentioned by (Florian, 2004); for example use protective dust covers for textile objects in storage area. Clean dust covers regularly. Undertake regular maintenance of storage areas. Display the textile objects inside airtight showcases. The environmental conditions should be controllable within the display showcases or storage storerooms. Temperature should be 18-22 °C and Relative

Humidity should be 45-55%. This can be achieved by build new storerooms with own air conditioning system and closing the windows in display area with installing air conditioning system. Replace the roof structure in atrium with sun protective roof. Also it is necessary controlling the RH in display showcases and storerooms using suitable buffer materials such as silica gill. If that it is impossible at least we should controlling the opining and closing the windows only when there is necessity for temperature change. For example open windows in favourable weather to introduce warm air into cold rooms. Repair leaking ceiling in storage area. Place portable ventilators in the museum halls. Set a suitable fumigant in display showcases and storerooms to reduce the chance of growing the micro organisms on the collections in the museum.

CONCLUSIONS

1- There are obvious excessive fungal infestations in all tested textile objects in both storage area and display showcases in the Museum of Jordanian Heritage, especially those obtained from the storage area.

2- The most dominant fungi isolated from tested samples belong to *Aspergillus, Penicillium, Chaetomium and Alternaria* species.

3- Among all tested textile fabrics Cellulosic fibers are more infested than protein fibers.

4- The causes of fungal infestations in the Museum of Jordanian Heritage may due to very poor environmental conditions used in display or storage of textile collection in the museum.

5- There is necessity for using one of the following fungicides to be used for disinfection of the biodeteriorated textiles in the Museum of Jordanian Heritage; Dichlorophene, Irgasan DP-300, Preventol O-Na, Preventol R-80 or Lichenicidia.

6- However it is necessity to carry out further research to evaluate suggested fungicides by investigation the long term effect of these fungicides on properties of dyed textiles in the Museum of Jordanian Heritage.

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