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Biology

A STUDY OF THE PRESENCE OF MICROFUNGI IN OLD AND RARE BOOK COLLECTIONS AND THEIR IMPACT

A. L. VARAGYAN [1*], S. G. MARGARYAN [2**]

[1] *Chair of Ecology and Nature Protection, YSU, Armenia*
[2] *Library after Sargis and Mari Izmirlians, YSU, Armenia*

The harmful effects of microfungi on library collections and human health have been considered. It has been proposed to change conditions for the safe preservation of books.

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Introduction. Fungi grow almost everywhere. Lacking chlorophyll, fungi feed on organic matter present in ready-made environments. Paper serves as a nutrient medium, consisting mostly of cellulose. A huge number of papers are damaged and decomposed by microorganisms, causing great harm. In addition to causing material damage, fungi inflict immense and irreparable damage to science by decomposing scientific, old, rare, and manuscript books, harming works of cultural art, and other materials of historical value. The growth of microfungi in a paper environment depends on several factors, e.g., the composition of the paper, the storage environment, air humidity, the temperature at which the paper or book is stored, book glues, and so on. It is noted, by the way, that the growth of different species of microorganisms can promote or suppress the growth of others. For example, bacteria suppress the growth of certain groups of fungi, while some species of fungi promote each other's growth. A quantitative increase in fungi on books is recorded when books are used. For example, after a book enters a library and is used by readers, 4 times more fungal spores are found on the books than before entering the library. The humidity factor is very important in book preservation, and keeping it below 55% is crucial [1, 2].

The composition of the air in workspaces differs from that of outdoor air. Microorganisms present in the air of workspaces can cause serious damage to employees' health [3]. Spores of numerous types of fungi in the air, upon entering the human body, cause various diseases, such as allergies. 20–25% of human health depends on the quality of the environment. A significant indicator of indoor air pollution is contamination by microfungi and their spores.

* E-mail: avaragyan@ysu.am
** E-mail: siranush.margaryan@ysu.am

Numerous studies have shown that more than 200 species of fungi are found in libraries and archives, 40 of which are permanent inhabitants. Among microfungi, molds are particularly dangerous for books, as they produce enzymes that decompose cellulose. These fungi can decompose 50% of the cellulose in paper within 2 months [4]. Molds are the primary inhabitants of libraries, museums, depositories, and similar places, and they are the main biodeteriorators of books, works of art, and archival documents. There are many historical facts and stories related to the harmful effects of molds, for example, "The Curse of the Pharaoh." Several archaeologists died during the opening of Tutankhamun's tomb. Years later, the cause of death was revealed to be the fungi *Aspergillus niger* and *Aspergillus flavus* found in the tomb. Another example of the greatest dangers posed by molds is their impact on the cultural heritage paintings and engravings found in the Lascaux Cave in France, dating back to the 18^{th}–15^{th} millennia BCE. However, microfungi growing in libraries and museums not only damage material objects, but can also cause great harm to the health of employees and visitors. These fungi secrete mycotoxins, which are toxic to humans.

Infection by microfungi is not limited to the pages of a book; it also spreads to the book's cover, binding threads, and glues. Paper infected with fungi may even be invisible to the naked eye, but infected paper becomes very weakened, brittle, and often has holes in that area. And if the entire page is infected, the pages can stick together.

To prevent the growth of spores in a room and to keep books in favorable conditions, temperature and humidity must primarily be controlled. Humidity should be between 50–55%, and the temperature at 17–19°C. In addition to this, sanitary-hygienic work and sterilization of books and documents must also be carried out [5, 6]. However, there are species that can survive even in poor conditions – at low temperatures and low humidity.

The most commonly encountered genera in library air and on book surfaces are *Alternaria, Aspergillus, Absidia, Acremonium, Cladosporium, Chaetomium, Chrysosporium, Eurotium, Fusarium, Geotrichum, Penicillium, Paecilomyces, Epicoccum, Phoma, Cunninghamella, Emericella, Scopulariopsis, Stachybotrys, Trichoderma*, and others.

Fungi present on the surfaces of cultural valuables are divided into 2 groups in terms of biodeterioration:

1. *Conditionally pathogenic fungi*, which grow on almost all surfaces in the presence of favorable humidity. Their enzymes are not capable of decomposing materials.

True material pathogens, which are capable of decomposing cultural valuables. Both groups of fungi can cause degradation, but only the second group can decompose the material [6].

Materials and Methods. The research was carried out in the laboratory of the Department of Botany and Mycology at the Faculty of Biology, Yerevan State University.

The object of the study is the air in the rooms of the Russian and foreign old printed literature collections of the Old and Rare Literature Department of the YSU Library, as well as the old printed books in Armenian and foreign languages kept in

that department. Samples were taken from old printed books dated 1717, 1802, 1822, and 1829, which were presumably infected with fungi, as the book pages were more brittle, damaged, and had spots of various colors.

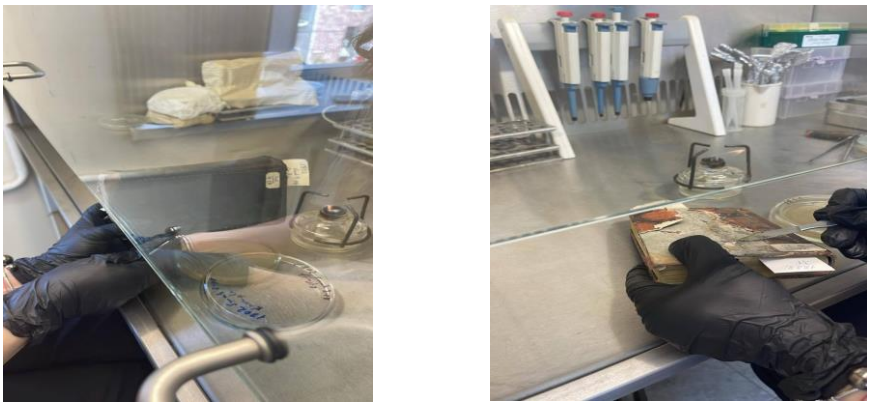

Fig. 1. Sampling from books in a sterile environment.

Two samples were taken from the 1717 book printed in French. The first sample was taken from the first page of the book, the second from the inner pages of the book. The sample from the 1822 book printed in French was taken from the decayed part of the book's cover. A sample from the 1829 book printed in English was taken from the paper side sections of the book. A sample from the 1802 book printed in Armenian was taken from the decayed, text-free section of the book's pages. A sample from the 1802 Armenian book was taken from the leather cover of the book. Air samples were taken by the aspiration method using an Aspirator PU-1B device. Malt extract agar was chosen as the medium for fungal growth in Petri dishes. Samples were taken in a sterile working environment in a Telstar DLF hood, complying with ISO and GMP standards (Fig. 1). After taking the samples, the Petri dishes were placed in a thermostat under 27°C conditions. The fungi were grown for 10 days.

Results and Discussion. The research results make it clear that the books are contaminated with fungi (Fig. 4, 5), and the air contains spores of the above-mentioned fungal genera. The results of the research are presented in Tabs. 1 and 2.

Table 1

Results of samples taken from books

Publication year of sampled book	Publication language of sampled books	Quantity of fungi species	Fungal genus
1717	French	×2 ×1	*Penicillium* *Cladosporium*
1717	French	×2	*Penicillium*
1802	Armenian	×1	*Penicillium*
1802	Armenian	×1	*Chaetomium*
1822	French	×1	*Penicillium*
1829	English	×0	–

Table 2

Results of samples taken from air

Sample	Quantity of species	Fungal genus
Air in the room of the foreign language rare book collection	2	*Aspergillus*
	1	*Penicillium*
	1	*Mucor*
	1	*Cladosporium*
Air in the room of the Russian language rare book collection	2	*Aspergillus*
	1	*Mucor*

Fungi of the *Aspergillus* genus include more than 300 species, which are widespread in nature. These are found in various ecosystems. The spore-forming apparatus of the representatives of the *Aspergillus* genus consists of a supporting foot (stipe) and a conidiophore thread rising upwards, which expands at the apical part into different shapes: cylindrical, columnar, pear-shaped, etc. The conidiogenous cells, on which the conidia develop, can be arranged in a single layer or a double layer [7].

Aspergillus fungi cause a number of infectious diseases called aspergillosis. *Aspergillus* fungi belong to the class of mold fungi. Some of these species have a negative impact on both human health and the environment. In humans, they cause allergic diseases of various kinds, such as allergic bronchopulmonary aspergillosis, which causes coughing, shortness of breath, and purulent discharge. Some species cause invasive aspergillosis, which is especially dangerous for people with chronic diseases.

A. fumigatus, *A. flavus*, and *A. niger* are the most well-known disease-causing species. Colonies of different *Aspergillus* species can have various colorations. In a culture medium, they usually grow within 3–4 days. *A. fumigatus* colonies are grey, with blue-green hues. *A. flavus* colonies are yellow, and *A. niger* colonies are black.

Some *Aspergillus* species secrete aflatoxins, which are carcinogenic substances. These substances can be present in various food products contaminated with *Aspergillus.*

*Aspergillu*s fungi are also strong biodegraders. They degrade paper, and their presence in libraries causes damage to books, especially in humid, poorly ventilated areas. These fungi produce enzymes called cellulases, which break down the cellulose in the paper. As a result of all this, already contaminated paper turns yellow and becomes brittle. *Aspergillus* spores are easily dispersed in the air, which in turn contaminates new books. Contamination is especially intense under conditions of high humidity (above 55%) [8–10].

Tab. 3 presents the degree of toxicity and the effect on human health of the fungi found in the rare and old books section.

As a result of the conducted research, it became clear that two species of *Aspergillus* fungi are present in the air of the rooms belonging to the Foreign Language Rare Book Collection and the Russian Language Rare Book Collection (Fig. 2, 3).

Samples taken from the covers and paper of early printed books dated 1717, 1802, and 1822 have revealed the presence of molds belonging to the genus *Penicillium* (Fig. 4, 5).

The mycelium of *Penicillium* representatives is composed of branched conidiophore threads, and the conidiophore apparatus resembles a brush; this is why it is called a brush mold. Fungal colonies of the *Penicillium* genus can have different colors [7].

Table 3

Toxic effect of detected fungi on human health

Fungal genus	Toxicity level	Health hazards
Aspergillus	High	Respiratory infections, eye irritation, allergies, secretion of mycotoxins, which have a carcinogenic effect
Chaetomium	High	Allergic reactions produce mycotoxins (Chaetoglobosins, Chaetomin, Emodin) which cause mutations
Penicillium	Medium	Penicilliosis disease, which may manifest during immunodeficiency, allergies; some species produce mycotoxins (e.g., citrinin, patulin)
Cladosporium	Medium	Allergic reactions, asthma exacerbations
Mucor	Low-Medium	Allergic and respiratory diseases, ischemic necrosis of tissues, rarely mucormycosis

Fig. 2. Air samples from the Foreign and Russian Language Rare Book Collections rooms, 5 days after inoculation.

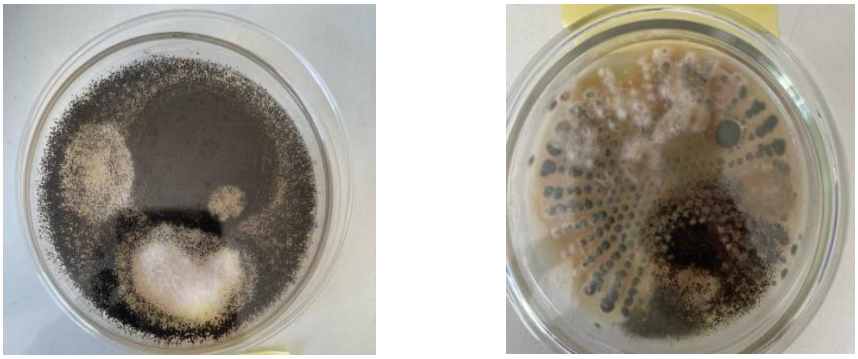

Fig. 3. Air samples from the Foreign and Russian Language Rare Book Collections rooms, 10 days after inoculation (*Aspergillus, Mucor, Penicillium, Cladosporium*).

Penicillium fungi are the causative agents of Penicilliosis disease. This disease manifests in combination with AIDS [8]. A large number of molds belong to the *Penicillium* genus; they are very common in poorly ventilated areas, the upper layer of soil, and elsewhere. They cause damage to many organic substances. The colonies are mostly blue, green, and turquoise in color.

Physiologically, these fungi are aerobic, but they can grow deep inside food products under conditions of minimal oxygen flow. They are acidophiles, as they grow in acidic environmental conditions.

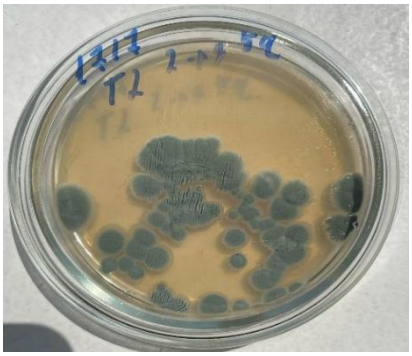

Fig. 4. Two species of *Penicillium genus* growing on the book from 1717.

Penicillium fungi are capable of cleaving organic compounds and using the resulting compounds for their growth and reproduction. This occurs due to the synthesis of hydrolytic enzymes, including amylase, cellulase, and xylanase. Many *Penicillium* species are used in various sectors of production, for example, in cheese production or medicine production. The drug of the penicillin group, which is an antibiotic, is obtained from this fungus [11].

By producing the enzyme cellulase, these fungi can break down the paper of books, as a result of which the paper becomes brittle and loses its elasticity. They can cause greenish stains on books, as well as break down organic glues, which leads to the disintegration of the book. They can also cause allergic diseases. Library staff members are particularly included in the target group [12].

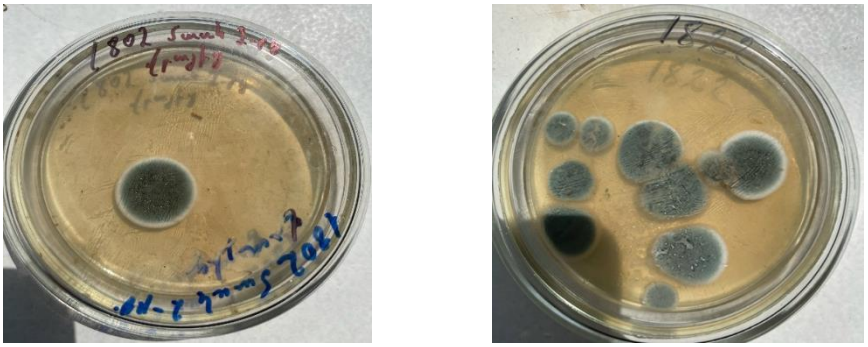

Fig. 5. One species of *Penicillium* grown from a sample taken from the cover and paper of the books from 1802 and 1822.

The causative agents of the disease mucormycosis are also *Mucor* fungi. Their spores are often found in the air. Infection with the disease can occur through the inhalation of spore-contaminated air. Rarely, it occurs by eating food contaminated via the gastrointestinal system. The pathogen affects the brain, eyes, lungs, and so on. These appear as soft gray cotton and can darken over time, and they are characterized by their very rapid growth (within a few hours). They are very stable with respect to temperature and can grow even at 40°C. These fungi can grow on

blood vessel walls and cause thrombi and embolisms, leading to ischemic necrosis of the surrounding tissues [8].

Among the molds, the species *Mucor mucedo* is widespread. The mycelium, penetrating into the substrate, such as food, is covered with a gray coating of aerial mycelium. The hyphae of the mycelium are colorless and may have one or more branched sporangiophore threads with sporangia that contain a large number of spores [7].

As a result of the research, *Mucor* fungi were grown in samples taken from the air of the foreign and rare book rooms.

Mucor fungi not only degrade paper, but can also degrade ink and affect the readability of the texts written in the book. They also cause allergic and respiratory diseases in humans [13].

Cladosporium fungi cause porosity (pitting) on books and cuts/fraying on the edges of the paper, as well as causing black or dark-colored stains. The colonies range in color from dark green to black. This dark coloration is due to the presence of melanin, which performs a protective function for the spores, for example, protecting against ultraviolet radiation. They also have a destructive effect on ink. These fungi cause a specific odor on books. They cause allergic reactions in humans, such as itching of the eyes and ears and nasal discharge [14].

As a result of the research, representatives of the *Cladosporium* genus were found in samples taken from the air of the foreign language rare book room and in the sample taken from the first page of the 1717 book (Fig. 6).

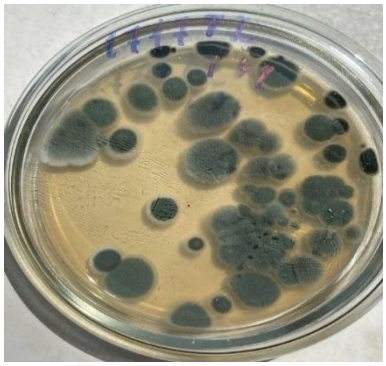

Fig. 6. Two species of *Penicillium* and one species of *Cladosporium* growing on the book from 1717.

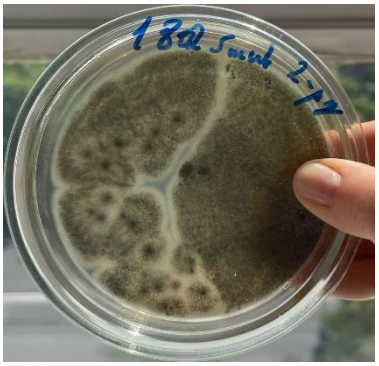

Fig. 7. One species of *Chaetomium genus* growing on the book from 1802.

Chaetomium fungi are cellulose degraders, which means they also degrade and damage books, documents, and works of art. The colonies can have gray or greenish hues. They are particularly dangerous for book repositories where appropriate conditions are not maintained. They also cause significant harm to human health, especially in individuals with weakened immune systems.

Favorable conditions for their growth are 25–28°C, but there are also representatives that are thermotolerant and can grow even at 40°C [15]. They produce mycotoxins (Chaetoglobosins, Chaetomin, Emodin), which affect human hereditary material, DNA, and cause mutations (Emodin), weaken the human

immune system, and can cause cancerous diseases (Chaetomin), while another group of toxins affects cell division processes (Chaetoglobosins) [16].

As a result of the research, a representative of the *Chaetomium* genus was found in the sample taken from the first page of the 1802 book (Fig. 7).

Conclusion. The results obtained from the conducted research confirm that the rare books in the Rare and Old Literature Department are not kept under the necessary conditions that is, the area is not ventilated, and the humidity and temperature conditions do not comply with the norms (the absence of any regulating device).

It is recommended to have regular ventilation of the area or the implementation of ventilation systems, continuous monitoring of room air quality, control of humidity and temperature conditions (30–50% and 16–20°C), and the installation of lamps with ultraviolet radiation in the rare book storage rooms.

Regular monitoring of the books is advised, especially in case of changes in conditions. If necessary, reprocessing of the books with antifungal agents is recommended.

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Ա. Լ. ՎԱՐԱԳՅԱՆ, Ս. Գ. ՄԱՐԳԱՐՅԱՆ

ՀԻՆ ԵՎ ՀԱԶՎԱԳՅՈՒՏ ԳՐՔԵՐԻ ՀԱՎԱՔԱԾՈՒՆԵՐՈՒՄ ՄԻԿՐՈՍՆԿԵՐԻ ԱՌԿԱՅՈՒԹՅԱՆ ՈՒՍՈՒՄՆԱՍԻՐՈՒԹՅՈՒՆ ԵՎ ԴՐԱՆՑ ԱԶԴԵՑՈՒԹՅՈՒՆԸ

Դիտարկվել է միկրոսնկերի վնասակար ազդեցությունը գրադարանային հավաքածուների և մարդու առողջության վրա: Առաջարկվել է փոխել գրքերի անվտանգ պահպանման պայմանները:

А. Л. ВАРАГЯН, С. Г. МАРГАРЯН

ИССЛЕДОВАНИЕ НАЛИЧИЯ МИКРОГРИБОВ В КОЛЛЕКЦИЯХ СТАРЫХ И РЕДКИХ КНИГ И ИХ ВОЗДЕЙСТВИЕ

Рассмотрены вредные последствия воздействия микрогрибов на библиотечные фонды и здоровье человека. Предложены изменения условий безопасного хранения книг.